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A Synoptic Study of the Water Quality of Whitefish River

Submitted to

Montana Department of Environmental Quality
1520 East Sixth Avenue
Helena, MT 59602-0901

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INTRODUCTION

This study was conducted by the Flathead Lake Biological Station (FLBS) to determine level of support of the designated beneficial uses identified by the Montana Water Use Classification System for the Whitefish River from Whitefish Lake outlet to the confluence with the Stillwater River. It estimates annual nutrient and sediment loads, identifies sources and quantifies longitudinal and seasonal changes in these inputs. It assesses probable causes and probable sources listed as reasons for including this water body on the 303(d) list. This work will be used to develop plans to bring water quality into compliance with applicable standards and protect it from future degradation. The data collected will be used to allocate nutrient loads in the Total Maximum Daily Loads (TMDL) document due at the end of the current calendar year.

The Whitefish River is currently on Montana's 303(d) list as threatened for partial support for aquatic life and cold water fishery - trout. Partial support signifies that one or more beneficial uses are not fully supported due to human activities. The probable causes listed include metals, nitrogen, nutrients, oil and grease, PCBs, priority organics and thermal modifications. The probable sources were identified as industrial point sources, silviculture, construction-land development and urban runoff/storm sewers. The Whitefish River was found to fully support Agriculture, Drinking Water Supply and Industrial beneficial uses. Primary Contact (recreation/swimming) beneficial use was not assessed.

The water quality studies and chemistry data used to make the partial support designation are dated (Bahls et al. 1979 and Nunnallee 1976) or not comprehensive enough (Stanford et al. 1997 and Bahls 1996) from which to allocate nutrient loads or determine sources and seasonal patterns in nutrient loading. As rivers flow from their source to their mouth, inputs from tributaries, groundwater, storm water drainage and point source discharges from industrial or sewage treatment plants alter water quality. The magnitude of impact these inputs have on water quality change with season and weather. Biological and chemical changes occur as the water flows downstream. The extent of these changes depends on season, weather and channel characteristics such as slope, insolation and riparian development, as well as floodplain development and connectivity. Synoptic water quality measurements are required to capture this temporal and spatial variance. Ideally, a multiyear study with sampling stations located above and below all major inputs and changes in channel characteristics would be used. Tributaries would be sampled just above confluence with the main channel. Sampling would be conducted

during the baseline and rising and falling limbs of all storm event hydrographs as well as that of the annual hydrograph. Due to time and budget constraints, this study was conducted over the course of one year. However, the sampling regimen has both the spatial and temporal resolution to fully address the needs of the Montana TMDL program.

The Whitefish River flows through the middle of the upper Flathead Basin between the Stillwater and Flathead Rivers. Its source is Whitefish Lake, a 13.2 km^2 oligotrophic lake. Although the first three kilometers are within the city limits of Whitefish, Montana, most of its course is over agricultural land. The final four kilometers are through light industrial and residential developments north of Kalispell, Montana. Its only major tributary, Haskill Creek, drains Big Mountain located at the southern tip of the Whitefish Range. All of this land is under increasing development pressure. Flathead County experienced a 26% growth rate over the last decade (Flathead Basin Stewardship Index 2002) and continues to be one of the top three counties in Montana for growth. The cities of Whitefish and Kalispell continue to annex land for development. Big Mountain Ski Resort, located at the headwaters of Haskill Creek, also continues to expand. As this development continues, water quality in Whitefish River will steadily decline if measures for sediment and nutrient abatement are not initiated. Higher housing densities increase nutrient loading from impervious surfaces, lawn fertilizer application and greater volumes of sewage treatment plant or septic tank drain field effluent. Increased sedimentation from construction and poor land management practices will smother periphyton communities and macrophyte beds, reducing the instream processes that reduce nutrient loads and impairing stream ecosystem productivity. This synergy of effects could rapidly diminish Whitefish River water quality unless careful management plans are crafted and implemented. This report offers remediation measures to lessen impacts from current and future development and land management practices. A monitoring program to track water quality trends and detect degradation also is offered.

METHODS

Study Site

The Whitefish River (waterbody: MT76P003_010 in Hydro Unit 17010210) flows from the outlet of Whitefish Lake, Flathead County, Montana (48.4156 latitude, -114.3540 longitude, elevation 914 m) 57 kilometers south to its confluence with the Stillwater River (48.2123 latitude, -114.2872 longitude, elevation 884 m) east of Kalispell, Montana. Its course is entirely

within Flathead County, Montana. Five river sites (Outlet, JP Road, USGS, Rose Crossing and Westwood) were selected for estimating nutrient loads with an additional site (Hwy 40) added in April. Four additional sites were sampled during synoptic sampling in the fall of 2004 to determine groundwater influence (Hogson Road, Birch Grove, Reserve Street and Evergreen). Figures 1–3 show river sampling site locations. Table 1 lists river sample sites and coordinates.

Tributaries to the river (listed in order starting from upstream) are Cow Creek, Haskill Creek, Walker Creek and Motchika Creek. The first three flow all year and were included as tributary sites. Motchika Creek is a very small, intermittent stream and was not included. Sampling sites were established at road crossings closest to the river. A street drain culvert (Culvert) under the 2nd Street North bridge was sampled on all dates to estimate nutrient inputs from the city of Whitefish, Montana. Figure 1 shows tributary sampling site locations. Table 1 lists tributary sample sites and coordinates.

Discharge

At the Outlet site, a datalogger (CR510, Campbell Scientific, Logan, Utah) with calibrated pressure transducer was used to continuously record staff height from April 23 through October 28, 2004. Discharge was measured on each sampling date using an acoustic Doppler flow meter (Flowtracker, Sontek/YSI Inc., San Diego, California) when water levels were low enough to allow wading. A staff to discharge relationship was calculated to estimate discharge from the datalogger data (Rantz 1982).

At all other sites, discharge was measured using the acoustic Doppler velocimeter on each sampling date when water levels allowed. Continuous discharge data were downloaded for the USGS site from the USGS website (http://waterdata.usgs.gov/mt/nwis/uv?12366000).

Temperature

Thermistor temperature loggers (8-bit TR, Vemco, Shad Bay, Nova Scotia, Canada) were tested for accuracy in a temperature bath at a range of 5–25 degrees Celsius. The loggers were deployed no later than April 23 at Outlet, JP Road, Highway 40, Rose Crossing and Westwood sites on the Whitefish River. At the Outlet site, the logger was wired to the staff gage 5 cm above the bottom of the stream. At the Highway 40 site, the logger was wired to a bridge support 1 m above the bottom of the stream. At the other three sites, the logger was attached to a one-half inch rebar that was driven into the bottom of the stream until the logger was 10 cm above the bottom of the stream. The loggers were retrieved on June 21, downloaded and

redeployed the same day. The logger at Highway 40 was not found. Subsequent searches at lower water levels did not turn up the missing logger. It is believed the wire attaching the logger to the bridge support wore through during high water. The remaining loggers were downloaded again in August and a final time on October 23.

Nutrients, Sediment and Metals

Depth-integrated water samples were collected from the stream center or culvert outflow (Culvert and Cow Creek sites) at each site and analyzed for nutrients and total suspended sediments. Nutrient samples were collected in acid-washed, 1 liter, high-density polyethylene containers. TSS samples were collected in 1 or 4 liter (depending on turbidity) distilled-water-rinsed, high-density polyethylene containers. The containers and caps were rinsed three times with sample water before filling. Specific conductivity and pH were measured with a conductivity, temperature and pH meter (Model ph/Con 10, Oakton Vernon Hills, Illinois). Dissolved oxygen was measured with a dissolved oxygen and temperature meter (Model 55 YSI, Sontek/YSI Inc., San Diego, California). Water samples were placed in coolers filled with ice for transport. Total alkalinity was measured immediately upon returning to the Flathead Lake Biological Station's Freshwater Research Laboratory. A 125 ml aliquot was filtered using a 0.45 µm nitrocellulose membrane filter (catalogue number HAWP-04700, Fisher Scientific, Pittsburg, Pennsylvania) and frozen pending $NO_3^- + NO_2^-$ and SRP analysis. A 250 ml aliquot of unfiltered sample water was frozen pending TPN and TP analysis. Samples were agitated throughout partitioning to keep particulate N and P suspended. All nutrient samples were analyzed with a segmented flow, colorimetric autoanalyzer (Model AA3, Seal Analytical Inc., Mequon, Wisconsin). Total suspended sediment samples were analyzed within 24 hours of sampling by filtration and gravimetric analysis. Table 2 lists all methods used in analysis.

Water samples for total recoverable metals concentrations were taken from river sites three times during the study. Outlet, Culvert, JP Road, USGS and Westwood sites were sampled during spring runoff on April 14, 2004 and again during fall baseline on September 8, 2004. Synoptic sampling for groundwater influence on metals concentrations occurred on October 26, 2004 (Outlet, JP Road, Highway 40, Hogson Road, USGS, Birch Grove, Rose Crossing, Reserve and Westwood). On all dates, depth-integrated samples were collected in acid-washed, 1 liter, high-density polyethylene containers from the thalweg or culvert outflow (Culvert site) and placed in ice-filled coolers for transport. In the laboratory, a 50 ml aliquot from each sample was

analyzed immediately for total alkalinity and the remainder (~950 ml) acidified to a pH of <2.0 with concentrated nitric acid. This was sent to the State of Montana Department of Public Health and Human Services Environmental Laboratory (DPHHS), Helena, Montana, for analysis. The spring runoff and fall baseline samples were analyzed for Hg (cold vapor technique, Environmental Protection Agency method 245.1), Ar, Ba, Be, Ca, Cd, Cr, Cu, Fe, Mg, Mn, Na, Pb, Se and Zn (total metal ICP scan, Environmental Protection Agency method 200.7). The synoptic samples were acidified with nitric acid to a pH of <2.0 and sent to DPHHS for Al, Ar, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Sr, Ti, V and Zn. Total hardness and sodium adsorption ratios (SAR) were calculated for each site from the results using the formula SAR = $[Na^+]/(0.5 \times [Ca^{2+}] + 0.5 \times [Mg^{2+}])^{1/2}$ where concentrations are expressed in millimoles per liter. Table 2 lists all methods used in analysis.

RESULTS AND DISCUSSION

Discharge

The Whitefish River discharge for the 2003–04 water year totaled 134 965 000 m^3. A low of 0.88 m^3s^{-1} was recorded on January 7, 2004. Daily mean discharge peaked on May 11 and 12 at 13.08 m^3s^{-1} (Figure 4). Due to a series of rain events in late summer and fall, the river never returned to baseflow during the study following spring runoff. The lowest flow after spring runoff was 2.26 m^3s^{-1} on August 17, 2004. A rain event on August 24–27 increased the discharge to 3.74 m^3s^{-1} and never dropped below 3.38 m^3s^{-1} for the rest of the study. These flows are 3 times greater, on average, than those from a year ago and above the 95 percentile for all flows on record.

The only tributary of any consequence is Haskill Creek, which was found to contribute up to 20% during its peak flow in mid-April. Walker and Cow Creeks contribute <3% and <1% to river discharge, respectively. Longitudinal variance of discharge was slight with a general increase from USGS to Westwood. This variance was so slight that differences between sites in channel characteristics that could potentially affect discharge measurements confounded determination of true differences in discharge from background noise (e.g., run versus riffle). An earlier study on Whitefish Lake (Craft et al. 2003) found outlet discharge measurements were nearly identical estimates from the USGS site throughout the year.

A natural characteristic of lake outflow rivers is a decrease in the height and a broadening of the base of spring runoff and storm event hydrographs. The large storage capacity of

Whitefish Lake effectively buffers the effects of spring snowmelt and storm events on the discharge in Whitefish River. This results in less erosional and depositional activity and therefore less floodplain development along the main channel. Therefore, water in the channel tends to stay in the channel with little lateral exchange.

Temperature

Lake outflows have elevated summer temperatures due to discharge being dominated by warm water from the epilimnion. Whitefish Lake is a dimictic lake with a large surface area. Once the lake thermally stratifies in the summer, the outflow into Whitefish River is entirely water from the epilimnion. An increase in epilimnion temperature will increase the river water temperature directly. Since there is little tributary or floodplain influence, the river water temperature will show a longitudinal increase on sunny days from insolation and radiant heat gain and a decrease on cloudy days from precipitation and radiant heat loss.

The large volume of Whitefish Lake results in it remaining a major influence in the river's thermal budget well into the fall and winter. Until the lake overturns, typically in late November (Craft et al. 2003 and Golnar and Stanford 1984), river water temperatures at the lake outlet will remain above 4° C. These temperatures will not reach the freezing point until after the lake stratifies and the surface temperatures approach 0° C. The Whitefish River will remain ice-free longer than any other river in the Flathead Basin excepting the Swan River below Swan Lake, which also is a lake outflow.

The highest water temperature was 25.56° C recorded on July 16 and August 17 at Rose Crossing (Figure 5). On these same days at the Outlet site, water temperature maximums were 22.41° C and 23.79° C, respectively. The increase of 3.15° C between Outlet and Rose Crossing on July 16 was the greatest longitudinal increase in water temperature during the study (Figure 5).

Nutrient and Total Suspended Sediment Loads

Annual nutrient loads were lowest at the lake outlet site and tended to increase downstream. Figures 6 and 7 show annual loads for all five synoptic river sites as well as those for the Whitefish Sewage Treatment Plant (STP). The effluent from this point source accounted for 100% of the annual load of nitrate + nitrite nitrogen (henceforth referred to as nitrate nitrogen) measured at the JP Road site located approximately 300 meters below the outflow. It accounted for 66% of the total persulfate nitrogen, 40% of the soluble reactive phosphorus and 18% of the total phosphorus. This treatment plant has a discharge of between 0.02 and 0.06

cubic meters per second, which ranges between 0.5 to 4% of the total discharge of the river. The disproportionately high degree of influence this effluent has on the river can be explained by the oligotrophic nature of the river source. At the Whitefish Lake outlet, nitrate and soluble reactive phosphorus concentrations are near or below detection limits. Total persulfate nitrogen and total phosphorus concentrations also are low and primarily organic in origin. Inputs from the STP dramatically increase the concentrations of these nutrients in the river. This is due as much to the low levels in the river as with the high levels in the effluent.

Nitrate nitrogen annual loads remained steady at around 6.3 metric tons until the lower portion of the river. The loads increased by 50% from the USGS Gage to the Rose Crossing Site and by another 50% from the Rose Crossing Site to the Westwood Site. Monthly nitrate loads (Figure 8) show the months from November through March having the greatest increase at the lower river sites. This is due to a number of factors. During the summer months, macrophyte and algal uptake may be suppressing nitrate concentrations. During the fall and winter months, groundwater makes up a greater proportion of the discharge. The higher housing density along the lower portion of the river may be increasing nitrate concentrations in the groundwater through septic drain field effluents and leached agricultural and lawn fertilizer. The river also is ideal habitat for migrating waterfowl in the fall and early winter due to late surface ice development. It also is used heavily in the spring as nesting habitat. A high density of waterfowl was observed during these times. This may play a role in nitrogen loading from the elimination of their wastes directly into the water. Nitrate data collected by both FLBS and United States Geological Survey at the USGS Gaging Station from May 1999 through the present (Figure 9) shows concentrations have remained fairly low in recent years. It also shows elevated concentrations in the fall and spring of every year with the exception of the fall of 2004. Concentrations did not reach as high a level as in the past during the fall of 2004 due to record high flows from heavy precipitation throughout the season. This reduced nutrient concentration and effects of nutrient loading through dilution.

Tributary inputs to nitrate loads were significant only during peak runoff and only from Haskill Creek. Figures 10 and 11 compare sample loads among the three tributaries (Haskill, Cow and Walker) and the river sites above and below them (JP Road and USGS Gage, see Figure 1 for map). Haskill Creek discharge peaked in April, accounting for 15–30% of the total discharge in Whitefish River as measured at the downstream USGS Gage site. Nitrate concentrations were 7–8

times higher than were those in the river upstream of the confluence. The resulting nitrate loads were 230% and 91% of those found in the river on April 14 and 25, respectively. The sampling on April 14 followed a storm event. This accounts for much of the steep increase in nitrate loads between the JP Road and USGS Gage sites during this month. A storm event sampled in August showed nitrate loads from Haskill Creek accounting for 19% of those in the river. At no other time during the sampling period were nitrate inputs from Haskill Creek greater than 6% of those in the river. Loads from the other two tributaries, Cow and Walker Creek, never exceeded 7% of those in the river and were usually well below 1%.

Total persulfate nitrogen annual loads were highest at the JP Road site (Figure 6). This is due to the Whitefish STP loading immediately upstream. Higher concentrations and higher discharge during the spring resulted in peak loading from March through June (Figure 12). Overland flow during spring runoff carries accumulated organic waste and detritus into the river, rising water flushes backwaters and side channels and macrophyte and attached algae are scoured by the high water and suspended sediment. Whitefish Lake was a proportionately greater source of TPN during the summer months due to plankton export. Most of the TPN was organic nitrogen, especially at Lake Outlet (97–99%). Loads decreased longitudinally from November 2003 through March 2004 (Figure 13). Discharge was less than 1.6 $m^3 s^{-1}$ this period (Figure 4). Loads increased or were unchanged longitudinally from April through October 2004 when discharge ranged from 2.25 to 13.1 $m^3 s^{-1}$. This suggests the ability of the Whitefish River to reduce organic nitrogen loads instream appears to be limited by stream bed area to discharge volume ratio. Filtering by stream macroinvertebrates and bacteriological breakdown would have diminishing effect as water volume increases. Historic TPN concentrations (Figure 14) show a seasonal trend with high concentrations during early spring runoff. There does not appear to be an increasing trend in concentrations at least during the months for which we have multiple years of data.

Tributary inputs to TPN loading relative to river loads showed the same general trend as did those for nitrate loads. Inputs were substantial from Haskill Creek during early spring runoff and storm events (Figure 15), accounting for 40% and 14% of the river load on April 14 and 28. Cow Creek and Walker Creek never accounted for more than 2% and 3.5%, respectively, of the instantaneous load measured at JP Road (Figure 16).

Soluble reactive phosphorus loads peaked in May during peak runoff with the USGS Gage site having the highest load overall (Figure 17). High discharge and higher concentrations

from a storm event on May 22 increased loading at all sites for this month. Whitefish Lake and Whitefish STP are the two main sources of the SRP in the river. Loads decreased downstream, in general, especially below the USGS site. This, plus the very low levels of SRP, indicates algal and macrophyte productivity is phosphorus limited making the river retentive of, and responsive to, phosphorus additions. An increase in SRP loading potentially could produce nuisance algal blooms. Soluble reactive phosphorus concentrations have remained low since 1996 (Figure 18). USGS data from 2001 and 2002 were not included due to analytical detection limits of 7 micrograms per liter.

Tributary inputs of SRP were substantial from Haskill Creek and to a lesser extent Cow and Walker creeks (Figures 19 & 20). Combined SRP loads from all three tributaries ranged from 5% to 105% of the load measured at JP Road Site with an average of 39%. The highest relative inputs occurred during storm events on August 7 (105%), April 14 (93%) and August 25 (78%). The August 7 storm event occurred after several weeks of dry weather, which may have allowed particulate accumulation on impervious surfaces.

Total phosphorus loads peaked during spring runoff from April through June (Figure 21). Increased discharge was primarily responsible for the increased loads. The total phosphorus pool in surface water has two major components, organic and inorganic. Phosphorus in the organic fraction comes from relatively large molecules (e.g., phospholipids, amino and nucleic acids) contained in transported detritus such as sloughed algae, animal waste, plankton and leaf fragments. The inorganic fraction is primarily phosphate and polyphosphate ions adsorbed on sediment particles and colloids. As discharge increases so does stream power and more sediment is entrained in the water column. However, stream gradient plays a synergistic role with discharge in increasing stream power. The higher the gradient the greater the effect discharge has on power. Since the Whitefish River has a relatively low gradient, increased discharge would have a moderate effect on increased transport. Therefore, the increase in TP concentrations during high discharge is modest. TP loads showed no correlation to total suspended sediment at the upper sites. Since the source of the river is a lake outlet, nearly all of the TP is plankton or particulates from atmospheric fallout at the Lake Outlet site; almost none is sediment adsorbed phosphate. The Whitefish STP effluent also has little sediment adsorbed phosphate due to effects of settling ponds and tertiary treatment. The effluent made up from 38% to 81% of the TP load at the JP Road site during baseflow (October 2003–March 2004, Figure 4). Dilution from high spring runoff resulted

in relative percents of 15% in April, 3% in May and 15% in June. As the river returned to near baseflow conditions, relative percentages increased to 32% in August. Unseasonably high flows from fall rain events decreased relative percentages to 13% by October. Total phosphorus loads showed significant correlation ($\alpha = 0.01$, two-tailed) to suspended sediment at all three of the lower sites. This indicates seasonal increases in TP loading may be coupled to land management activities that increase bank erosion and soil loss. River TP concentrations have remained fairly low since 1995 (Figure 22).

Tributary inputs of TP were substantial only for Haskill Creek, primarily during rain events (Figures 23 and 24). It added an additional 123% to the load measured at the JP Road site on April 14, 55% on both August 7 and 25 and 28% on July 1. Haskill Creek TP concentrations showed significant correlation ($\alpha = 0.01$, two-tailed) to suspended sediment.

Annual total suspended sediment (TSS) loads showed a general longitudinal increase (Figure 25). USGS Gage and Rose Crossing Sites are riffle sites with slightly higher gradients than the others, so slightly higher values would be expected. However, Westwood site is a low gradient run habitat. Having the highest suspended sediment loads is indicative of excessive surface runoff, erosion and bank failure upstream. Monthly TSS loads showed seasonal trends patterned after peaks in discharge (Figure 26). Increased overland flow during snow melt, saturated stream banks and an increase in the erosive power of the river all contribute to this pattern. Concentrations from samples collected at the USGS Gage site from 1999 to 2004 show the same seasonal trend with no apparent annual increase (Figure 27).

Tributary inputs of TSS were substantial only for Haskill Creek (Figures 28 and 29). During the rain event on April 14, Haskill Creek carried 10.8 times the suspended sediment load of the Whitefish River at JP Road. It carried 1.5 times the load calculated for the JP Road site during a rain event on August 25. The flashy nature of the watershed, amounts of construction and poor land management activities on this drainage make Haskill Creek a serious source of sediment impairment to the Whitefish River.

Metals

Except for lead, total recoverable metal concentrations were below Human Health and Aquatic Life Standards (acute and chronic) at every site sampled (Table 3). The Lake Outlet sample collected on September 8, 2004 had 0.009 mg lead per liter, which is above the Aquatic Life Standard for chronic exposure of 0.0026 mg per liter (as calculated from sample hardness

value). Since this was a single sample and not a 96 hour average it does not meet the criteria for chronic evaluation. Other sample data were insufficient to determine if the level of lead remains above the chronic level. Detection limits for lead were 0.01 mg per liter and 0.005 mg per liter for samples collected during spring runoff and fall baseline, respectively. These are above the Aquatic Life Standard for chronic exposure of approximately 0.003 mg per liter as calculated from hardness data from the same samples.

Detection limits for beryllium were 0.01 mg per liter for samples collected during spring runoff. This is above the human health standard of 0.004 mg per liter. Iron and manganese concentrations in the effluent from the storm drain culvert under the 2nd Street Bridge in Whitefish, MT exceeded the Secondary Maximum Contaminant Level for surface waters. These criteria are based on aesthetic properties such as taste, odor and staining. Barium, calcium, magnesium and sodium concentrations also were very high in this effluent. These results suggest this effluent is of an anthropogenic origin and should be tested for other species of pollutants.

The water in Whitefish River would be characterized as moderate in hardness (Table 3) and suitable for domestic use. Sodium adsorption ratios calculated for samples collected during spring runoff and fall baseline flow ranged from 0.08 to 0.15. These values are well below the threshold of 4.0 commonly used as a maximum for suitability as irrigation water.

Stormwater Runoff

Three major rain events were sampled and compared to samples collected during a dry period, either after the rain event, as in April and September, or before, as in May. These rain event/dry period couplets were compared among four river sites (Lake Outlet, USGS Gage, Rose Crossing and Westwood) and Haskill Creek. The Lake Outlet site was used to determine if shoreline runoff has an impact on solute concentrations. JP Road was omitted due to the overriding influence of Whitefish STP on solute concentrations. The culvert was omitted due to very high background levels of all solutes. Cow and Walker Creeks were omitted due to their lack of importance on Whitefish River loads.

Total alkalinity was used as a semiconservative tracer to judge the potential confounding influence of different groundwater inputs between sampling periods. Groundwater in the Evergreen Aquifer has approximately twice the alkalinity of Whitefish River water (Craft and Ellis 2004). Higher alkalinity at a site between one point in time and another would indicate increased groundwater input relative to discharge. Higher nutrient concentrations would be the

result of an increase in loading by the groundwater. However, if alkalinity decreases as discharge increases due to a rain event, any increase in nutrient concentrations would be the result of storm water runoff having higher concentrations than the river. Alkalinity concentrations were lower during the storm event sampling for every sampling couplet except the Lake Outlet samples during May, which was only slightly higher (Figure 30). These results indicate higher nutrient concentrations during the rain event in these comparisons would suggest significant stormwater runoff additions.

Nitrate concentrations sampled during the April rain event were nearly double those sampled during the dry period at all locations on the lower half of the river (Figure 31). The rain event took place midway through the rising limb of the annual hydrograph (Figure 4) and would be expected to flush the mobile portion of the nitrogen pool from the backwaters, side channels and lowland areas. Soil saturated from snowmelt would result in increased surface runoff from pasturelands adding to the load. Rain event concentrations were slightly higher for the May couplet. These were taken just after the peak in spring runoff when flushing of accumulated dissolved nitrogen was nearly over. The late summer couplet showed little difference between the dry and wet event. Riparian plant communities, especially established annuals, and drier soil conditions may have retained the dissolved nutrients. Increased uptake by established aquatic autotrophs may be responsible for removed nitrate from the water column once it reached the river. Concentrations at Lake Outlet increased by an order of magnitude during May. Although lake overturn would increase nitrate concentrations, temperature data indicate the lake overturned in early April and was well stratified by this time. Shoreline inputs would have to be substantial to Haskill Creek concentrations increased during every rain event, most dramatically during the late summer storm.

Total persulfate nitrogen concentrations followed the same pattern as nitrate for the April couplet as would be expected during the rising limb of the annual hydrograph (Figure 32). Little difference was detected during the May couplet. Large numbers of waterfowl were observed at the lower three sites during the dry sampling event and the water had a distinct sewage smell. Loading from waterfowl excrement during the dry event may have equaled the amount flushed by the rain event and therefore masked the effect. The late summer couplet showed an increase in TPN concentrations at all sites during the rain event. Since TPN concentrations are dominated by organic nitrogen, little uptake by riparian and aquatic autotrophs would be expected. Lake

Outlet concentrations were much lower in general and showed little difference samples. Haskill Creek concentrations increased during every rain event.

In general, SRP concentrations do not show much of a response to storm events due to adsorption to suspended sediment and rapid uptake by phosphorus limited aquatic autotrophs. However, concentrations increased by over 70% during the rain event in May (Figure 33) at all river sites. An increase in SRP found throughout the river suggests the input was not from localized runoff but from a more basin wide phenomenon. Calculations based on sample loads reveal the input would need to have a concentration of at least 15.1 µg/l. A study conducted on Whitefish Lake found SRP concentrations in precipitation samples of 233 and 180 µg/l on May 24 and 30, 2002 (Craft et al. 2003). SRP of this level could overwhelm retention from biological uptake and sediment adsorption. At no other date during the two year study did precipitation samples exceed 80 µg/l. Spring weather patterns and slash pile burning could result in high precipitation SRP loads. Haskill Creek showed a decrease during the event, but total suspended sediment levels increased form 0.9 to 30.0 mg/l and may have adsorbed the increase. The late summer couplet showed elevated SRP concentrations during the rain event only at the Westwood Site. The housing development and increased road density in the lower stretch of the river would increase impervious surface area. This would contribute a greater amount of SRP to the stormwater input. The low suspended sediment load and shorter river length would decrease retention.

Overall, TP showed no patterned response to, or substantial difference between rain events and dry periods at the river sites (Figure 34). However, Haskill Creek showed increases for all periods. These concentrations were significantly correlated to suspended sediment ($\alpha = 0.05$, two-tailed). The source of the TP was probably soil loss and bank erosion due to poor land management practices upstream.

Total suspended sediment concentrations were much higher at the two lower sites during the rain event in the April couplet (Figure 35). Rapidly rising discharge and increased surface runoff due to saturated soils would increase total suspended sediment during this time of year. There was little difference in TSS concentrations between rain events and dry period sampling for the rest of the river couplets. May concentrations were high overall, but either nearly equal or lower during the rain event. Haskill Creek samples showed very dramatic differences in TSS concentrations. As with TP, the source was soil loss and bank erosion due to poor land management practices upstream.

Groundwater Influence

Use of discharge measurements to determine groundwater inputs was confounded by differences in measurement due to channel characteristics overriding actual differences in discharge. Instead, total alkalinity was used to estimate groundwater influence. During spring runoff (April through July), river discharge greater than 5 m3 s-1 masked the groundwater signal. Therefore, only samples taken before or after this period were used. Total alkalinity measured at synoptic sites showed a seasonal pattern of longitudinal increase during baseflow conditions (Figure 36). This suggests only the stretch of river below the USGS Gage has significant groundwater inputs (Figure 3). The difference in sample loads between the sites was divided by the approximate total alkalinity of groundwater in the Evergreen Aquifer (Craft and Ellis 2004) to estimate volume of groundwater added to the stream on each date. These results compared reasonably well to the differences in discharge measured between sites (Figure 37.) Estimated groundwater inputs averaged 0.068 $m^3 s^{-1}$ between USGS Gage and Rose Crossing and 0.20 $m^3 s^{-1}$ between Rose Crossing and Westwood. This would comprise 3.5% and 10% of median baseflow. Increases in groundwater contamination from fertilizer leaching, septic tank drain fields, gravel mining, or infiltration from salvage yards and impervious surface runoff could have serious impacts on the water quality of the lower Whitefish River.

CONCLUSIONS

The Whitefish River is a lake outlet, lowland river. Algal and periphyton productivity is phosphorus limited and nutrient concentrations are generally low. The dampening effect of Whitefish Lake on the discharge from the upper basin and the low gradient of the valley make the river susceptible to impacts from increased sediment loading owing to the inability to transport material. The natural lack of an extensive flood plain limits the degree of solute transformation as the river flows downstream. The river course is through real estate with high probability for housing and commercial development. These facts make the Whitefish the most threatened river in the Flathead Basin. FLBS makes the following recommendations regarding the listing of impairments as probable causes for partial support of Beneficial Uses. FLBS recognizes that Montana Department of Environmental Quality is the only entity that has the legal authority to make effective these determinations.

One of the Whitefish River beneficial use designations is cold water fishery - trout. This is in error and has caused the water body to be listed incorrectly for thermal modifications. River

temperatures routinely exceed 20° C from July through late August. This is a natural phenomenon due to the dominance of Whitefish Lake on the thermal budget of the river. Warm surface water from the lake makes up over 85% of the discharge in the river during the summer months. The thermal inertia of this mass and the lack of floodplain exchange create a cool-water fishery rather than a cold water fishery. There is little in the way of local anthropogenic influence at play.

Two of the probable causes for partial support listing were nitrogen and nutrients. Both nitrate and total persulfate nitrogen concentrations reach levels higher than those found in any other large river in the Flathead Basin. Mean concentrations of all four major nutrients (nitrate, TPN, SRP and TP) from water samples collected over the past five years on the lower Swan River were half of the concentrations of those collected at the USGS Gage site on the Whitefish River during the same period. The lower Swan River also is a lake outlet, low gradient river with phosphorus limited productivity just like the Whitefish River. The main differences between the rivers are length, type and extent of land development, and volume of sewage treatment plant effluent. This demonstrates the degree of anthropogenic influence on the Whitefish River. Since productivity is phosphorus limited and the nitrogen levels are relatively high, impacts of increased phosphorus loading are amplified. Nuisance algal blooms and oxygen depletion from decomposition could result. The partial support listing is justified in the context of nitrogen and nutrients as probable causes.

Metals also were listed as a probable cause for inclusion of the Whitefish River on the 303(d) list for partial support of its beneficial use designation. Lead was the only metal found to exceed state water quality criteria and only for chronic exposure. Detection levels at the State of Montana Department of Public Health and Human Services Environmental Laboratory were too high to allow further assessment. Until further sampling is done and samples analyzed at lower detection levels, metals should remain as a probable cause for inclusion on the 303d list.

Although oil and grease were not included in the scope of this study, it is worth noting that substantial oil deposits were detected in the river sediments at JP Road. According to Kelly Schmitt, Brownsfield Coordinator, MTDEQ, there are a number of such deposits in the river sediments and shoreline soils. Oil and grease should remain as a probable cause for partial support listing.

Sediment should be added to the list of probable causes for impairment. Dense macrophyte beds cover up to two-thirds of the river bottom in the slow moving, soft bottom sections of the river. Easily visible around the Highway 40 bridge, these beds provide quality habitat for a host of macroinvertebrates including decapods, amphipods and burrowing Ephemeroptera. These animals, in turn, provide forage for fish, birds and mammals. Increasing sediment loads have begun to impact this habitat in the upper reaches of the river. It is suspected that entrained sediment from City Beach in Whitefish, MT is reaching the river. The combination of this and inputs from construction sites and road sanding have smothered macrophyte beds to well below JP Road. Interviews with long-time residents along this stretch of the river confirm that the riverbed has changed from a soft bottom to a sand bottom over the past 5–10 years. An even more striking impact was observed below the mouth of Haskill Creek. Negative impacts to macrophyte beds were apparent from the confluence to over a kilometer downstream. Since the lake attenuates peaks in spring discharge, the hydraulic power of the river is insufficient to remove most of this sediment. If the sedimentation continues, the river bottom will become increasingly sandy, and since sand is poorly suited as habitat for either macrophytes or macroinvertebrates, stream ecosystem function will be severely degraded.

The Whitefish River has two major point sources of pollution, Whitefish Sewage Treatment Plant effluent (nutrients) and Haskill Creek (nutrients and sediment). The Whitefish STP is a tertiary treatment plant. The only practical improvement over current practice would be land application of effluent during the summer. The flashy nature of Haskill Creek coupled with poor land management practices upstream has made it a serious threat to Whitefish River water quality and ecosystem function. Better education of landowners on buffer vegetation and the impact of livestock grazing, through watershed advisory groups, would be a start to lessening the impact. Of critical importance is preserving and increasing what retention there is in the last kilometer of Haskill Creek. This section is a meandering stretch with beaver ponds and well-developed riparia. Removal of these ponds due to land development would result in a loss of the sediment and nutrient retention they provide. This would significantly degrade Whitefish river water quality and ecological function below the confluence.

The major nonpoint sources of pollution are fertilizer leachate from agricultural land and lawns, animal wastes from waterfowl and livestock, effluents from septic system drain fields and sediment from agricultural land, construction sites and City Beach, Whitefish, MT. These reach

the river through overland flow during spring and storm event runoff or through groundwater inputs. Control and reduction of these loads would include increased riparian buffer zones, sewering of all new developments with tertiary treatment of wastes, and a jetty built between City Beach and Whitefish Lake Outlet. Most important is denying river alterations such as riprap, levees, dikes and especially channelization.

Continued commercial and residential development along the Whitefish River corridor necessitates an increase in water quality monitoring. The monitoring needs to be done as close to the confluence with the Stillwater River as possible in order to assess impacts from land development. The Flathead Lake Biological Station has included the Stillwater River as a core monitoring site since 1985. This site is located 1.3 km below the confluence with the Whitefish River. This site provides information on overall water quality on the Stillwater Basin as a whole, but not on the Whitefish River in particular. This year the Whitefish River site at Westwood was added to the list of core monitoring sites included in the Flathead Lake Biological Station's Flathead Monitoring Project, which is submitted for funding to the state legislature. It would be sampled 15 times annually with chloride, sulfate, dissolved organic carbon, ammonium and soluble total phosphate included to the suite of analytes measured. Unfortunately, funding history for this project has been spotty. The USGS gaging station has been moved to the lower section of the river at the request of the Montana Department of Natural Resources and Conservation. This is an improvement over the previous location on Tetrault Road, but water quality samples will be collected only 4 times per year. This is insufficient to accurately assess loads or detect impacts in a timely manner. Synoptic sampling, performed during spring runoff and late fall baseflow, should be done at least once every five years and should include the main sites sampled in this study. The data collected would be instrumental in assessing sources of degradation. This monitoring not only would be used to assess impacts to Whitefish River, but also as a tool for understanding future impacts from development on the other rivers in the Flathead Basin.

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Table 1. Sampling Site Coordinates.

Site Name	Latitude	Longitude
Whitefish River @ Whitefish Lake Outlet	48.4155	-114.3539
Whitefish River @ JP Road Bridge	48.3856	-114.3295
Whitefish River @ Highway 40 Bridge	48.3712	-114.3026
Whitefish River @ Hogson Road Bridge	48.3419	-114.2739
Whitefish River @ USGS Gage on Tetrault Road	48.3206	-114.2783
Whitefish River @ Birch Grove Bridge	48.2911	-114.2892
Whitefish River @ Rose Crossing Bridge	48.2565	-114.2872
Whitefish River @ Reserve Drive Bridge	48.2404	-114.2924
Whitefish River @ Evergreen Drive Bridge	48.2259	-114.2923
Whitefish River @ Westwood Lane Bridge	48.2188	-114.2859
Culvert under 2nd Street Bridge, Whitefish, MT	48.4106	-114.3426
Cow Creek	48.4013	-114.3278
Haskill Creek	48.3889	-114.3096
Walker Creek	48.3835	-114.2909

Table 2. Biophysical variables and methods used in monitoring water quality.

Variable (units)	Method (references)	Detection Limit
Nutrients		
phosphorus (µg/l-P)		
total	persulfate digestion; modified automated ascorbic acid (1)	0.4
soluble reactive	filt.; mod. auto. ascorbic acid (1)	0.4
nitrogen (µg/l-N)		
total persulfate	persulfate digestion (2); auto. cadmium reduction (1)	20.0
nitrite + nitrate	auto. cadmium reduction (1)	2.0
total alkalinity (mg/l-CaCO3)	titration (1)	0.5
Metals(mg/l)		
Al, Ar, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sb,Se, Sr, Ti, V and Zn	inductively coupled plasma atomic emission (1)	varied
Hg	cold vapor atomic absorption (1)	0.5
TSS (mg/l)	filtration (1)	10.0
Physical profiles		
temperature (°C)	thermistor (3)	0.15
dissolved oxygen (ppm)	electrode (3)	0.2
pH (units)	electrode (4)	0.10
conductivity (µmhos/cm)	electrode (4)	1.5

[1]APHA 1998

[2]D'Elia et al. 1977

[3]measured in situ using Model ph/Con 10, Oakton, Vernon Hills, IL

[4]measured in situ using Model 55 YSI, Sontek/YSI Inc., San Diego, CA

Table 3. Total recoverable metal concentrations and aggregate properties of water samples from selected sites on the Whitefish River (WFR), the Stillwater River and Spring Creek near Kalispell, MT, and a storm drain culvert under the 2nd Street Bridge in Whitefish, MT during 2004 spring runoff and fall baseline flow. Mercury was analyzed with cold vapor technique (Environmental Protection Agency method 245.1) All other metals were analyzed by ICP scan (EPA method 200.7). Units are in milligrams per liter.

									Aquatic Life Standards for Cd				Aquatic Life Standards for Cr III	
Site	**Date**	**Al**	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Acute**	**Chronic**	**Co**	**Cr**	**Acute**	**Chronic**
WFR Outlet	4/14/2004	NA	<0.01	NA	0.060	<0.01	25.3	<0.01	0.0019	0.0002	NA	<0.01	1.6	0.09
Culvert, 2nd Street Bridge	4/14/2004	NA	<0.01	NA	**0.300**	<0.01	94.2	<0.01	0.0071	0.0006	NA	<0.01	4.7	0.27
WFR JP Road	4/14/2004	NA	<0.01	NA	0.060	<0.01	25.9	<0.01	0.0019	0.0003	NA	<0.01	1.7	0.09
WFR USGS	4/14/2004	NA	<0.01	NA	0.070	<0.01	26.9	<0.01	0.0020	0.0003	NA	<0.01	1.7	0.09
WFR Westwood	4/14/2004	NA	<0.01	NA	0.080	<0.01	27.2	<0.01	0.0020	0.0003	NA	<0.01	1.7	0.09
WFR Outlet	9/8/2004	<0.02	<0.005	<0.01	0.054	<0.002	24.3	<0.002	0.0018	0.0002	<0.01	<0.002	1.6	0.09
Culvert, 2nd Street Bridge	9/8/2004	0.03	<0.005	0.08	**0.391**	<0.002	98.9	<0.002	0.0073	0.0007	<0.01	<0.002	4.9	0.27
WFR JP Road	9/8/2004	0.05	<0.005	<0.01	0.057	<0.002	25.2	<0.002	0.0019	0.0002	<0.01	0.004	1.6	0.09
WFR USGS	9/8/2004	**0.38**	<0.005	0.04	0.058	<0.002	25.4	<0.002	0.0019	0.0002	<0.01	<0.002	1.6	0.09
WFR Westwood	9/8/2004	**0.46**	<0.005	0.05	0.098	<0.002	29.2	<0.002	0.0022	0.0003	<0.01	<0.002	1.8	0.10
WFR Outlet	10/26/2004	<0.02	<0.005	<0.1	0.059	<0.002	25.8	<0.002	0.0019	0.0003	<0.01	<0.002	1.7	0.09
WFR JP Road	10/26/2004	<0.02	<0.005	<0.1	0.063	<0.002	26.5	<0.002	0.0020	0.0003	<0.01	<0.002	1.7	0.09
WFR Hwy 40	10/26/2004	0.03	<0.005	<0.1	0.070	<0.002	27.5	<0.002	0.0020	0.0003	<0.01	<0.002	1.7	0.09
WFR Hogson Rd	10/26/2004	0.04	<0.005	<0.1	0.070	<0.002	27.7	<0.002	0.0021	0.0003	<0.01	<0.002	1.7	0.10
WFR USGS	10/26/2004	0.04	<0.005	<0.1	0.062	<0.002	27.9	<0.002	0.0021	0.0003	<0.01	<0.002	1.8	0.10
WFR Birch Grove	10/26/2004	0.04	<0.005	<0.1	0.070	<0.002	28.4	<0.002	0.0021	0.0003	<0.01	<0.002	1.8	0.10
WFR Rose Crossing	10/26/2004	0.04	<0.005	<0.1	0.072	<0.002	29.3	<0.002	0.0022	0.0003	<0.01	<0.002	1.8	0.10
WFR Reserve St	10/26/2004	0.04	<0.005	<0.1	0.078	<0.002	29.5	<0.002	0.0022	0.0003	<0.01	<0.002	1.8	0.10
WFR Westwood	10/26/2004	0.04	<0.005	<0.1	0.087	<0.002	31.1	<0.002	0.0023	0.0003	<0.01	<0.002	1.9	0.11
Spring Creek @ Hwy 2	10/26/2004	<0.02	<0.005	<0.1	**0.321**	<0.002	60.3	<0.002	0.0047	0.0005	<0.01	<0.002	3.4	0.19
Stillwater @ Kalispell	10/26/2004	0.05	<0.005	<0.1	0.077	<0.002	37.0	<0.002	0.0027	0.0003	<0.01	<0.002	2.2	0.12
Human Health Standards*		--	0.018	--	2.0	0.004	--	0.005			--	0.1		
Aquatic Life Standards*, Acute		0.750	0.340	--	--	--	--				--			
Aquatic Life Standards*, Chronic		0.087	0.150	--	--	--	--				--			

*Circular WQB-7, Montana Numeric Water Quality Standards

Table 3, continued. Total recoverable metal concentrations and aggregate properties of water samples from selected sites on the Whitefish River (WFR) at selected sites, the Stillwater River and Spring Creek near Kalispell, MT, and a storm drain culvert under the 2nd Street bridge in Whitefish, MT during 2004 spring runoff and fall baseline flow. Metals were analyzed by ICP scan (EPA method 200.7). Units are in milligrams per liter.

			Aquatic Life Standards for Cu										Aquatic Life Standards for Ni	
Site	**Date**	**Cu**	**Acute**	**Chronic**	**Fe**	**Hg**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Acute**	**Chronic**
WFR Outlet	4/14/2004	<0.01	0.012	0.008	<0.01	<0.0002	NA	6.0	<0.01	NA	1.2	<0.02	0.4	0.05
Culvert, 2nd Street Bridge	4/14/2004	<0.01	0.043	0.026	**0.92**	<0.0002	NA	21.7	**0.29**	NA	20.2	<0.02	1.3	0.14
WFR JP Road	4/14/2004	<0.01	0.013	0.009	0.03	<0.0002	NA	6.2	<0.01	NA	1.4	<0.02	0.4	0.05
WFR USGS	4/14/2004	<0.01	0.013	0.009	0.08	<0.0002	NA	6.1	<0.01	NA	1.6	<0.02	0.4	0.05
WFR Westwood	4/14/2004	<0.01	0.013	0.009	0.16	<0.0002	NA	6.3	0.02	NA	1.5	<0.02	0.4	0.05
WFR Outlet	9/8/2004	<0.002	0.012	0.008	0.02	<0.0002	1.0	5.9	<0.005	<0.01	1.1	<0.01	0.4	0.05
Culvert, 2nd Street Bridge	9/8/2004	0.003	0.044	0.026	**0.61**	<0.0002	4.0	21.6	**0.449**	<0.01	13.8	<0.01	1.3	0.15
WFR JP Road	9/8/2004	<0.002	0.012	0.008	0.08	<0.0002	1.0	6.1	<0.005	<0.01	1.5	<0.01	0.4	0.05
WFR USGS	9/8/2004	<0.002	0.012	0.008	0.07	<0.0002	1.0	6.1	0.009	<0.01	1.9	<0.01	0.4	0.05
WFR Westwood	9/8/2004	<0.002	0.014	0.009	0.12	<0.0002	1.0	7.1	0.018	<0.01	2.5	<0.01	0.5	0.05
WFR Outlet	10/26/2004	<0.002	0.013	0.009	<0.01	NA	1.0	6.3	<0.005	<0.01	1.2	<0.01	0.4	0.05
WFR JP Road	10/26/2004	<0.002	0.013	0.009	0.02	NA	1.0	6.5	<0.005	<0.01	1.6	<0.01	0.4	0.05
WFR Hwy 40	10/26/2004	<0.002	0.013	0.009	0.05	NA	1.0	6.6	<0.005	<0.01	1.7	<0.01	0.5	0.05
WFR Hogson Rd	10/26/2004	<0.002	0.014	0.009	0.05	NA	1.0	6.6	<0.005	<0.01	1.7	<0.01	0.5	0.05
WFR USGS	10/26/2004	<0.002	0.014	0.009	0.05	NA	1.0	6.6	<0.005	<0.01	1.7	<0.01	0.5	0.05
WFR Birch Grove	10/26/2004	<0.002	0.014	0.009	0.04	NA	1.0	6.7	<0.005	<0.01	1.8	<0.01	0.5	0.05
WFR Rose Crossing	10/26/2004	<0.002	0.014	0.009	0.04	NA	1.0	7.0	<0.005	<0.01	1.8	<0.01	0.5	0.05
WFR Reserve St	10/26/2004	<0.002	0.014	0.009	0.04	NA	1.0	7.0	<0.005	<0.01	1.9	<0.01	0.5	0.05
WFR Westwood	10/26/2004	<0.002	0.015	0.010	0.06	NA	1.0	7.6	0.009	<0.01	2.3	<0.01	0.5	0.06
Spring Creek @ Hwy 2	10/26/2004	<0.002	0.029	0.018	0.02	NA	1.4	16.3	0.009	<0.01	4.6	<0.01	0.9	0.10
Stillwater @ Kalispell	10/26/2004	<0.002	0.018	0.011	0.07	NA	1.0	8.5	0.01	<0.01	1.8	<0.01	0.6	0.06
Human Health Standards*		1.3			--	0.0005	--	--	--	--	--	0.1		
Aquatic Life Standards*, Acute					--	0.0017	--	--	--	--	--			
Aquatic Life Standards*, Chronic					1.0	0.00091	--	--	--	--	--			
Secondary Maximum Contaminant Level*					0.3	--	--	--	0.05	--	--	--		

*Circular WQB-7, Montana Numeric Water Quality Standards

Table 3, continued. Total recoverable metal concentrations and aggregate properties of water samples from selected sites on the Whitefish River (WFR) at selected sites, the Stillwater River and Spring Creek near Kalispell, MT, and a storm drain culvert under the 2nd Street bridge in Whitefish, MT during 2004 spring runoff and fall baseline flow. Metals were analyzed by ICP scan (EPA method 200.7). Units are in milligrams per liter.

			Aquatic Life Standards for Pb								Aquatic Life Standards for Zn				
Site	**Date**	**Pb**	**Acute**	**Chronic**	**Sb**	**Se**	**Sr**	**Ti**	**V**	**Zn**	**Acute**	**Chronic**	**Alk[1]**	**Hard[2]**	**SAR[3]**
WFR Outlet	4/14/2004	<0.01	0.1	0.003	NA	<0.05	NA	NA	NA	<0.01	0.1	0.1	84.9	87.9	0.08
Culvert, 2nd Street Bridge	4/14/2004	<0.01	0.4	0.014	NA	<0.05	NA	NA	NA	0.04	0.3	0.3	314.8	324.6	0.69
WFR JP Road	4/14/2004	<0.01	0.1	0.003	NA	<0.05	NA	NA	NA	<0.01	0.1	0.1	88.0	90.2	0.09
WFR USGS	4/14/2004	<0.01	0.1	0.003	NA	<0.05	NA	NA	NA	<0.01	0.1	0.1	86.1	92.3	0.1
WFR Westwood	4/14/2004	<0.01	0.1	0.003	NA	<0.05	NA	NA	NA	<0.01	0.1	0.1	89.3	93.9	0.1
WFR Outlet	9/8/2004	0.009	0.1	0.003	<0.005	<0.05	<0.05	0.092	<0.005	<0.005	0.1	0.1	93.0	85.0	0.07
Culvert, 2nd Street Bridge	9/8/2004	<0.005	0.4	0.015	<0.005	<0.05	0.18	0.334	<0.005	<0.005	0.3	0.3	289.3	335.9	0.46
WFR JP Road	9/8/2004	<0.005	0.1	0.003	<0.005	<0.05	<0.05	0.095	<0.005	<0.005	0.1	0.1	97.7	88.0	0.1
WFR USGS	9/8/2004	<0.005	0.1	0.003	<0.005	<0.05	**0.48**	0.952	<0.005	<0.005	0.1	0.1	94.6	88.5	0.12
WFR Westwood	9/8/2004	<0.005	0.1	0.003	<0.005	<0.05	**0.54**	1.100	<0.005	<0.005	0.1	0.1	111.2	102.2	0.15
WFR Outlet	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.098	<0.005	<0.005	0.1	0.1	82.9	90.4	0.08
WFR JP Road	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.067	<0.005	<0.005	0.1	0.1	87.3	92.9	0.1
WFR Hwy 40	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.103	<0.005	<0.005	0.1	0.1	87.3	95.8	0.11
WFR Hogson Rd	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.101	<0.005	<0.005	0.1	0.1	90.3	96.3	0.11
WFR USGS	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.095	<0.005	<0.005	0.1	0.1	90.3	96.8	0.11
WFR Birch Grove	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.104	<0.005	<0.005	0.1	0.1	90.3	98.5	0.11
WFR Rose Crossing	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.105	<0.005	<0.005	0.1	0.1	96.2	102.0	0.11
WFR Reserve St	10/26/2004	<0.005	0.1	0.003	<0.1	<0.05	<0.05	0.072	<0.005	<0.005	0.1	0.1	94.7	102.5	0.12
WFR Westwood	10/26/2004	<0.005	0.1	0.004	<0.1	<0.05	<0.05	0.113	<0.005	<0.005	0.1	0.1	99.2	109.0	0.14
Spring Creek @ Hwy 2	10/26/2004	<0.005	0.2	0.009	<0.1	<0.05	0.08	0.206	<0.005	<0.005	0.2	0.2	192.4	217.7	0.19
Stillwater @ Kalispell	10/26/2004	<0.005	0.1	0.004	<0.1	<0.05	<0.05	0.126	<0.005	<0.005	0.1	0.1	116.9	127.4	0.1
Human Health Standards*					0.008	0.05	4.0	--	--						
Aquatic Life Standards*, Acute					--	0.02	--	--	--						
Aquatic Life Standards*, Chronic					--	0.005	--	--	--						

*Circular WQB-7, Montana Numeric Water Quality Standards

[1]Total Alkalinity expressed as mg $CaCO_3$ per liter

[2]Hardness expressed as mg $CaCO_3$ per liter

[3]Sodium Adsorption Ratio

Figure 1. Map of Upper Whitefish River, Flathead County, Montana.

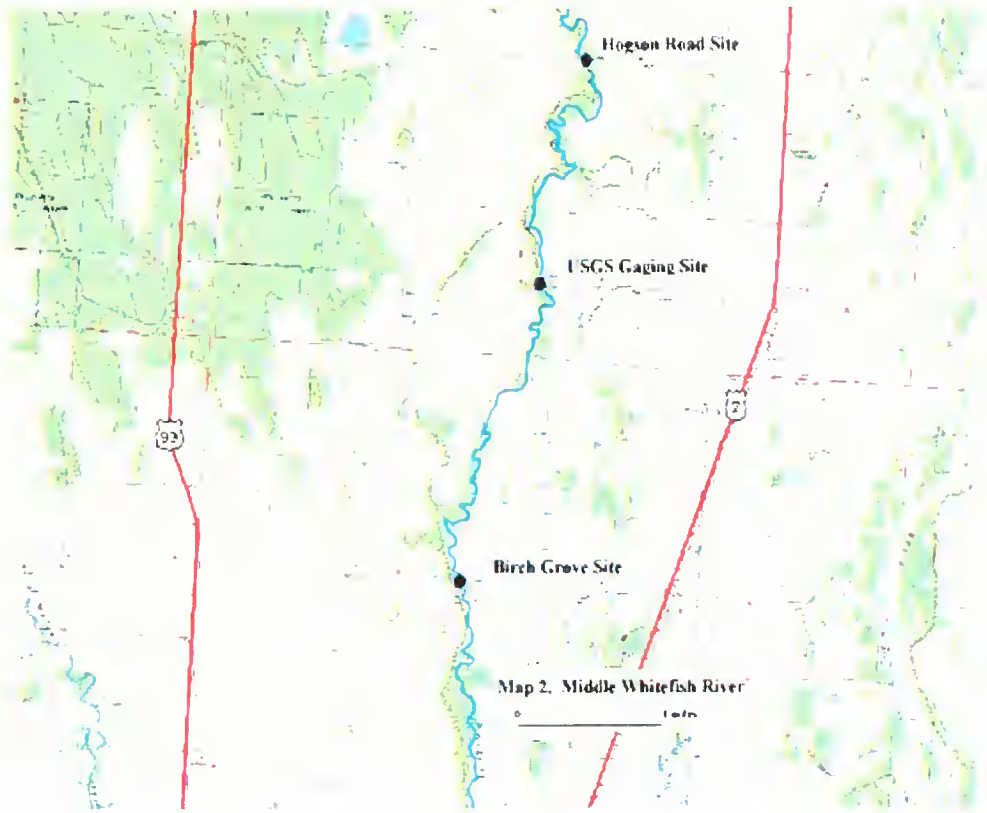

Figure 2. Map of middle sections of Whitefish River, Flathead County, Montana.

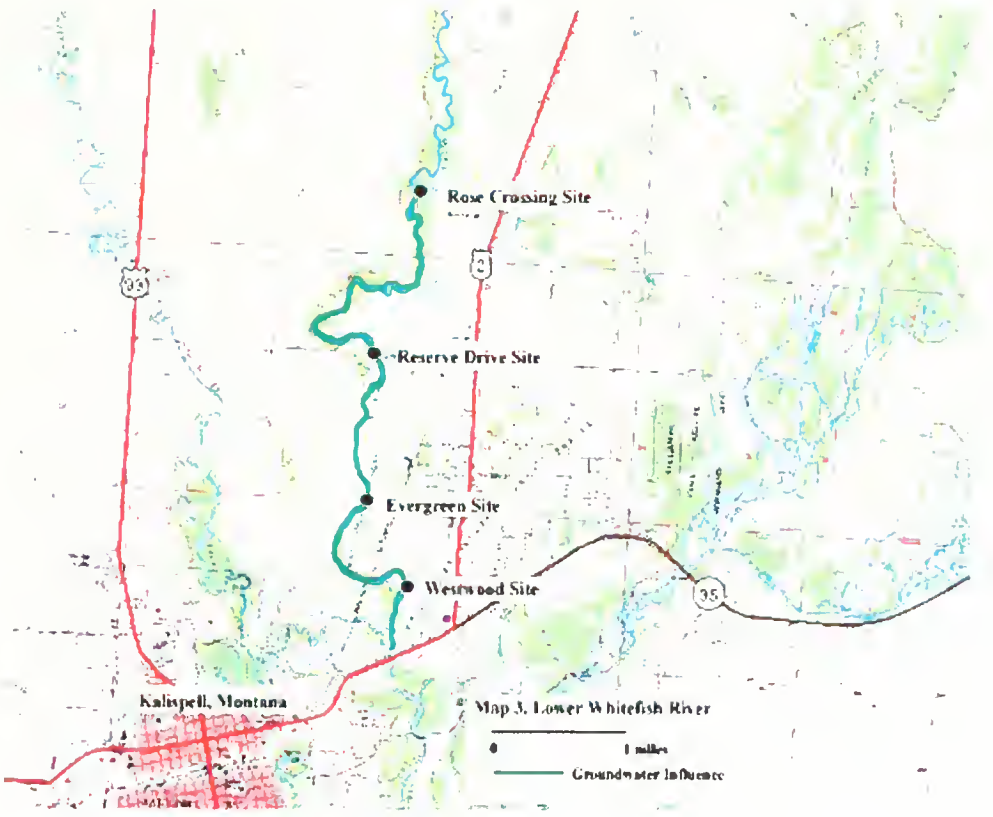

Figure 3. Map of lower section of Whitefish River, Flathead County, Montana.

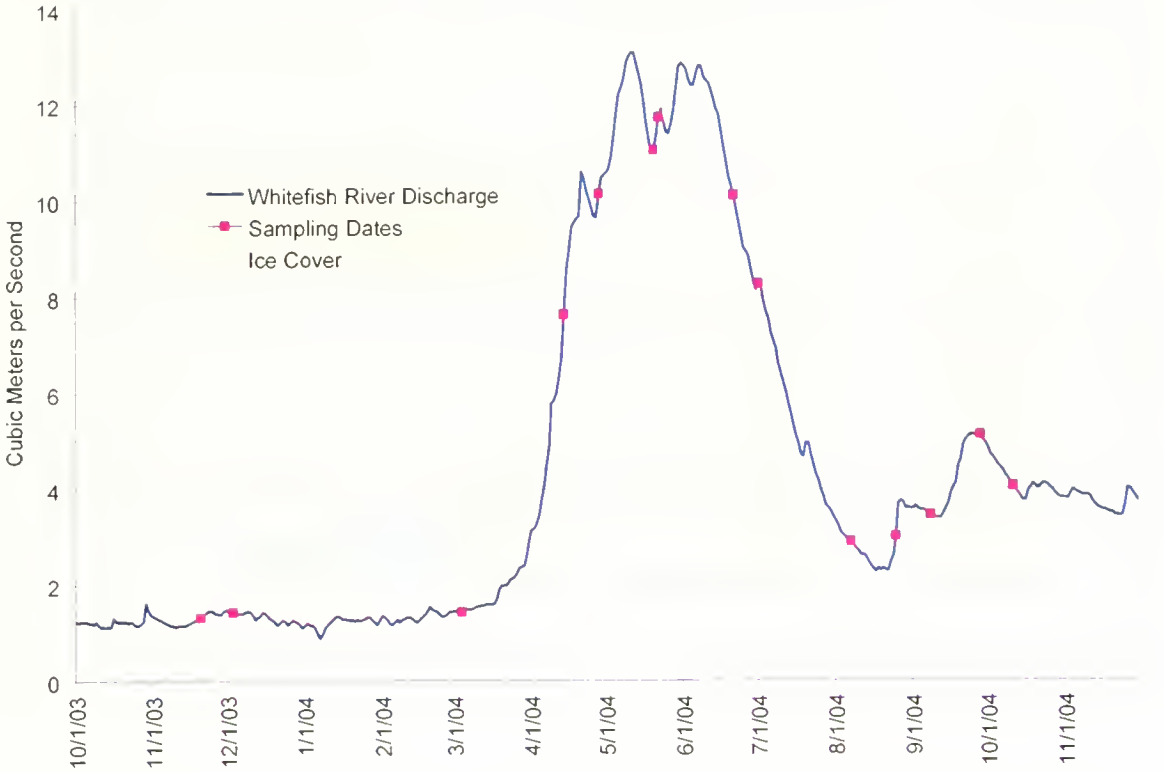

Figure 4. Whitefish River Discharge from October 2003 through November 2004.

Figure 5. Whitefish River water temperature from late April through late October 2004.

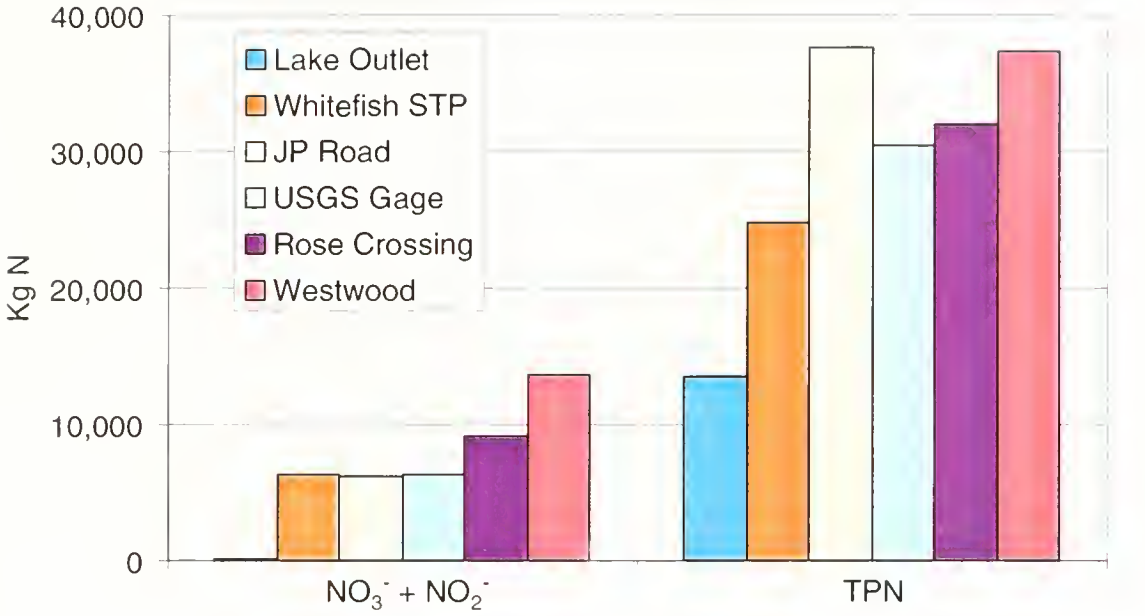

Figure 6. Whitefish River annual nitrogen loads at synoptic sites, water year 2003-04.

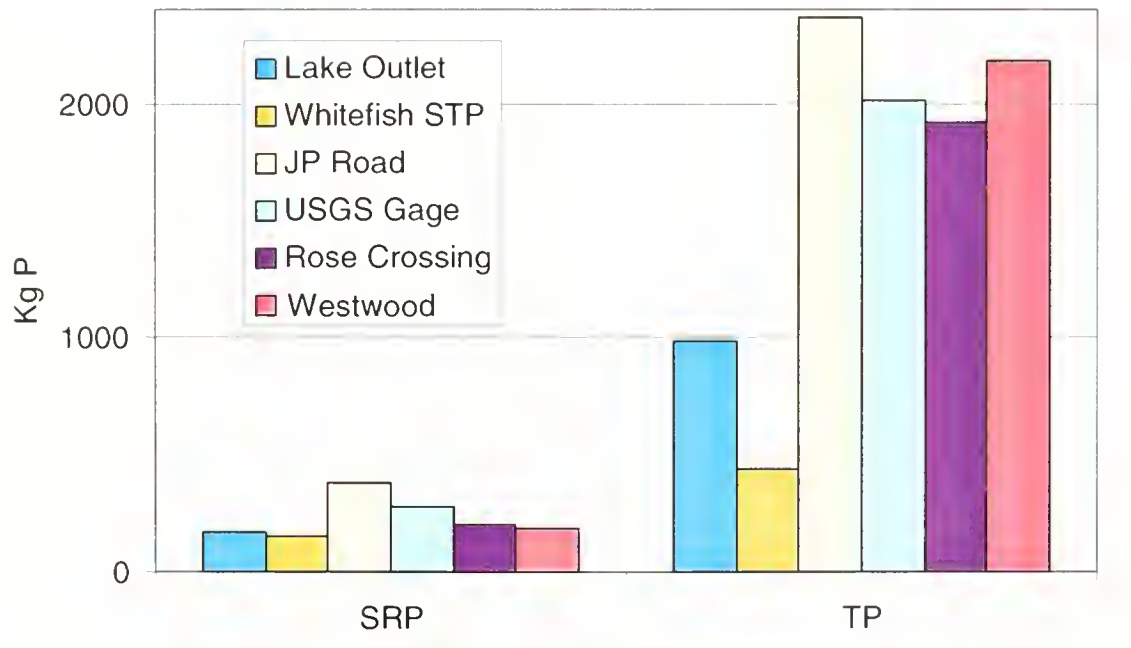

Figure 7. Whitefish River annual phosphorus loads at synoptic sites, water year 2003-04.

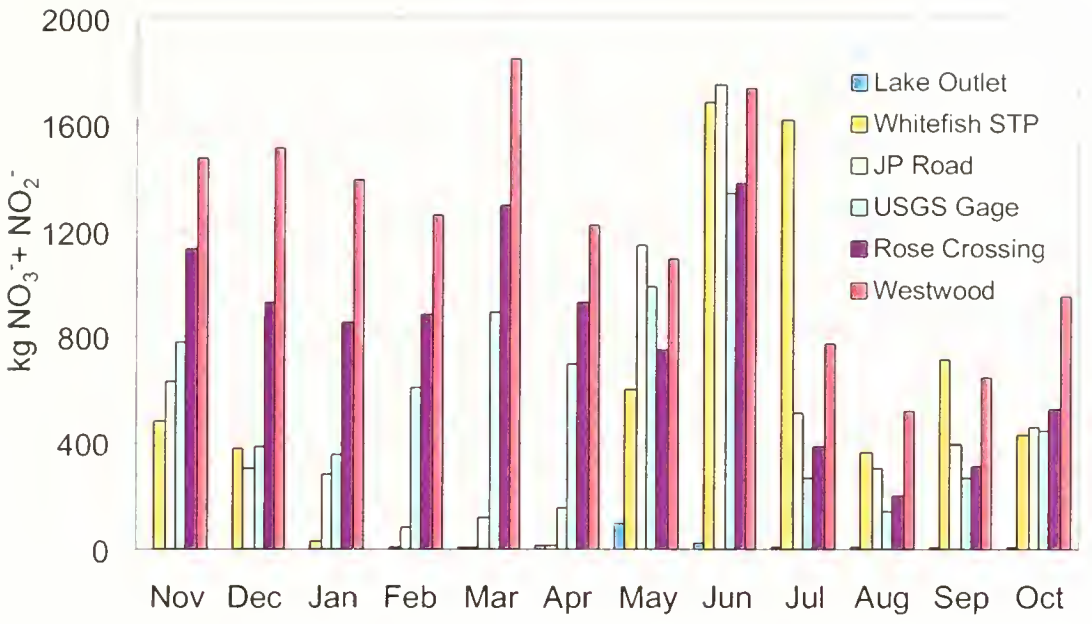

Figure 8. Whitefish River monthly nitrate + nitrite loads at synoptic sites, water year 2003-04.

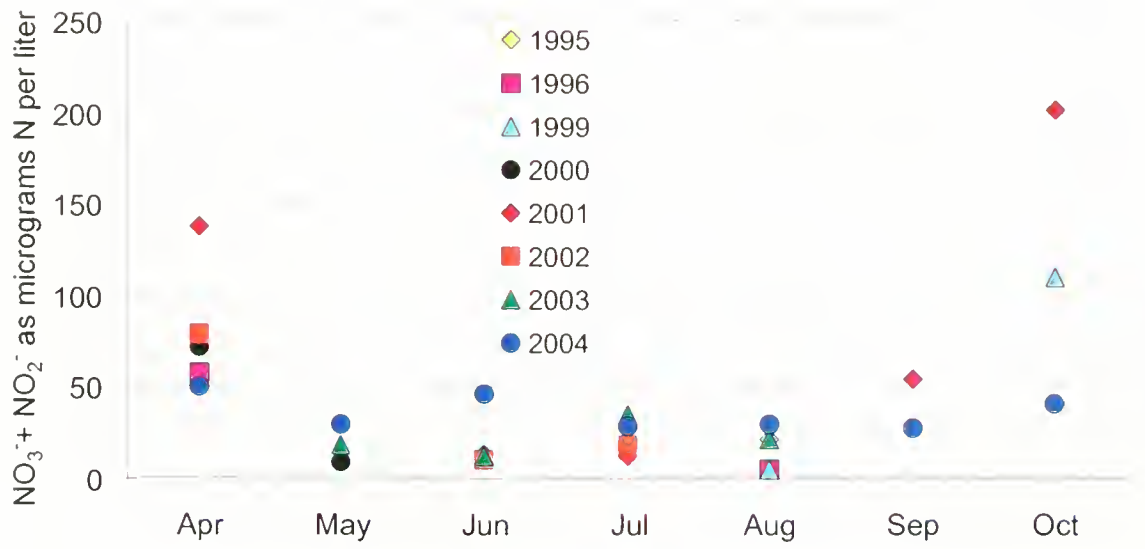

Figure 9. Whitefish River nitrate + nitrite concentrations at USGS Gaging site, April 1995 through October 2004.

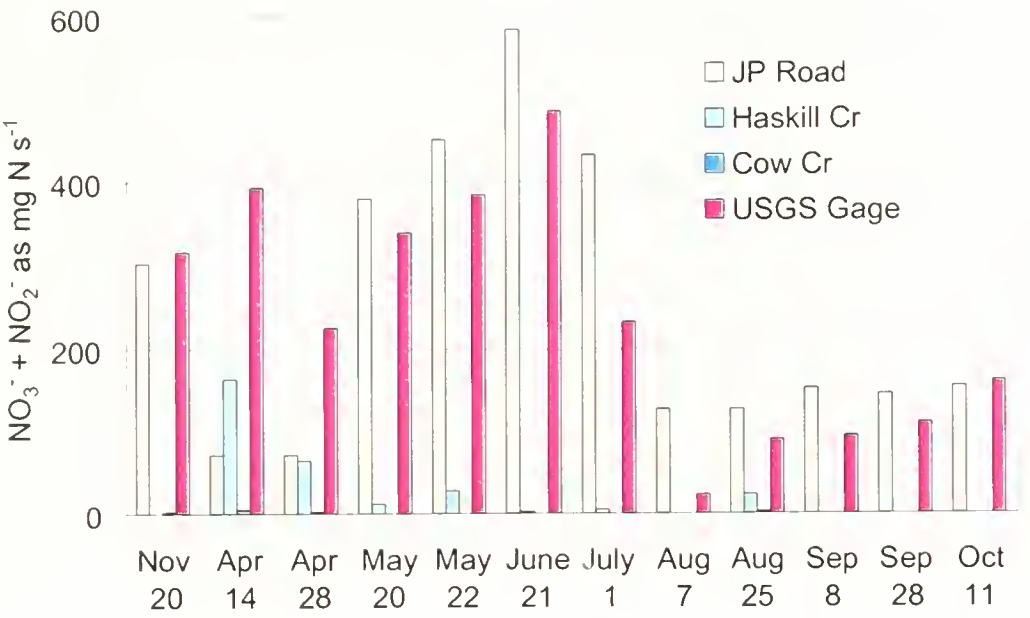

Figure 10. Sample nitrate + nitrite loads for Whitefish River at JP Road Bridge and USGS Gage, Haskill Creek, and Cow Creek, Flathead County, MT, from November 2003 through October 2004.

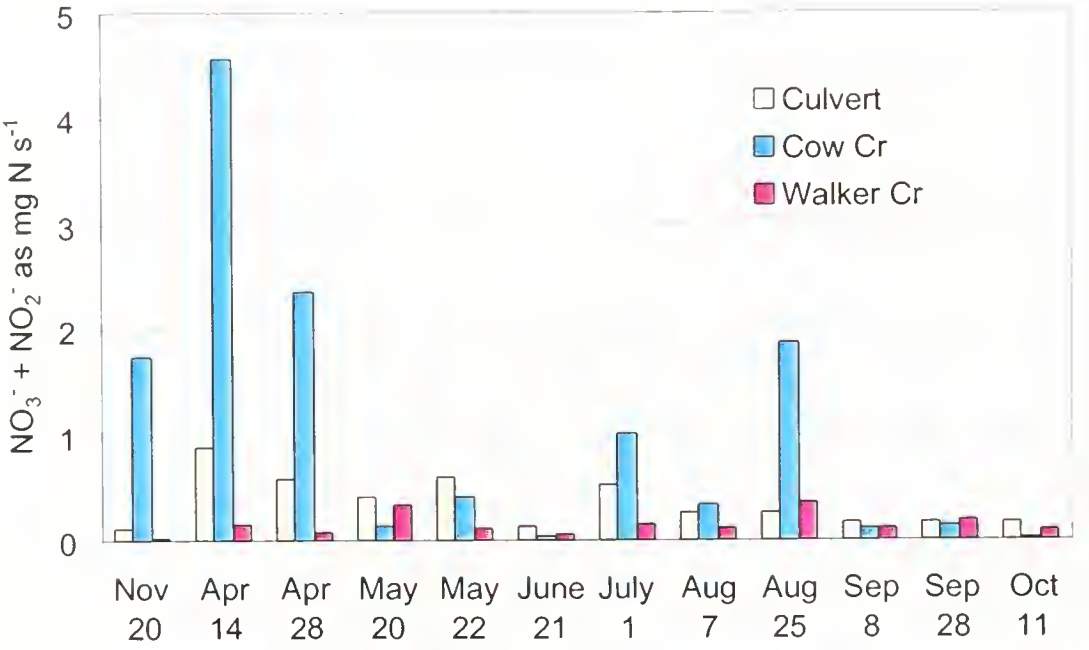

Figure 11. Sample nitrate + nitrite loads for storm drain culvert under West Second Street bridge in Whitefish, MT, Cow Creek and Walker Creek, Flathead County, MT, from November 2003 through October 2004.

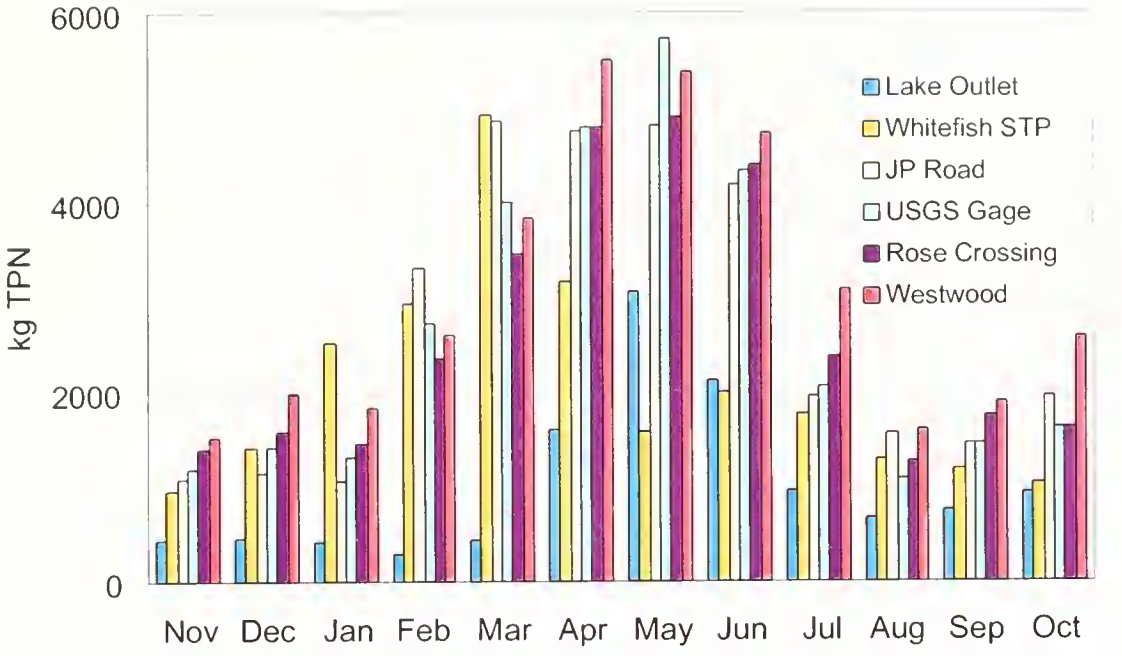

Figure 12. Whitefish River monthly total persulfate nitrogen loads at synoptic sites, water year 2003-04.

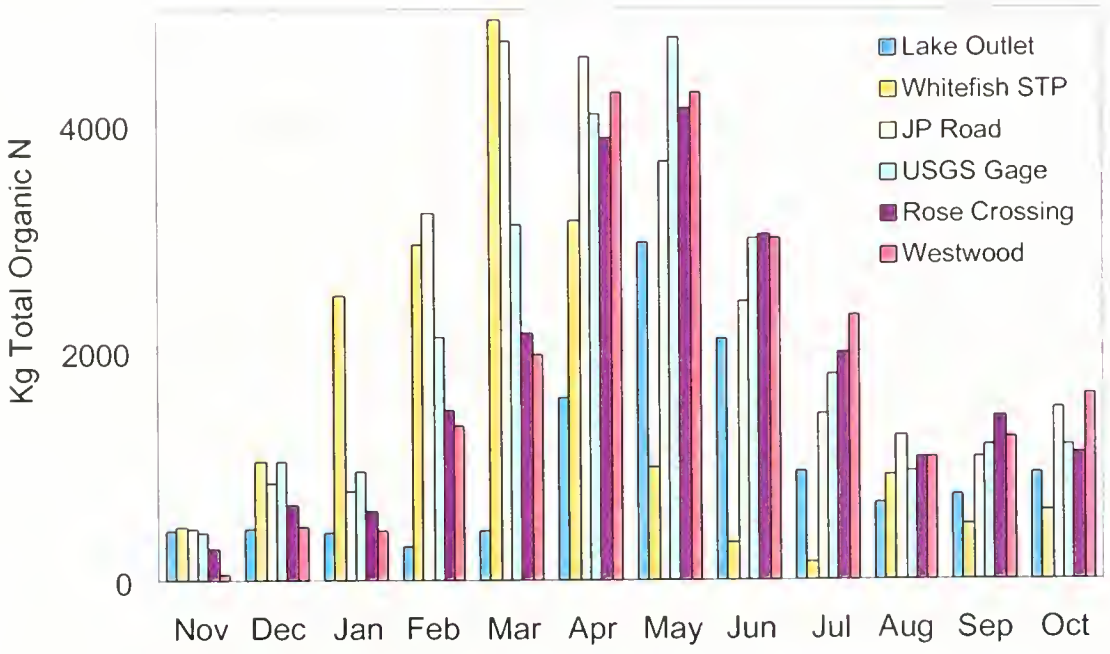

Figure 13. Whitefish River monthly total organic nitrogen loads at synoptic sites, water year 2003-04.

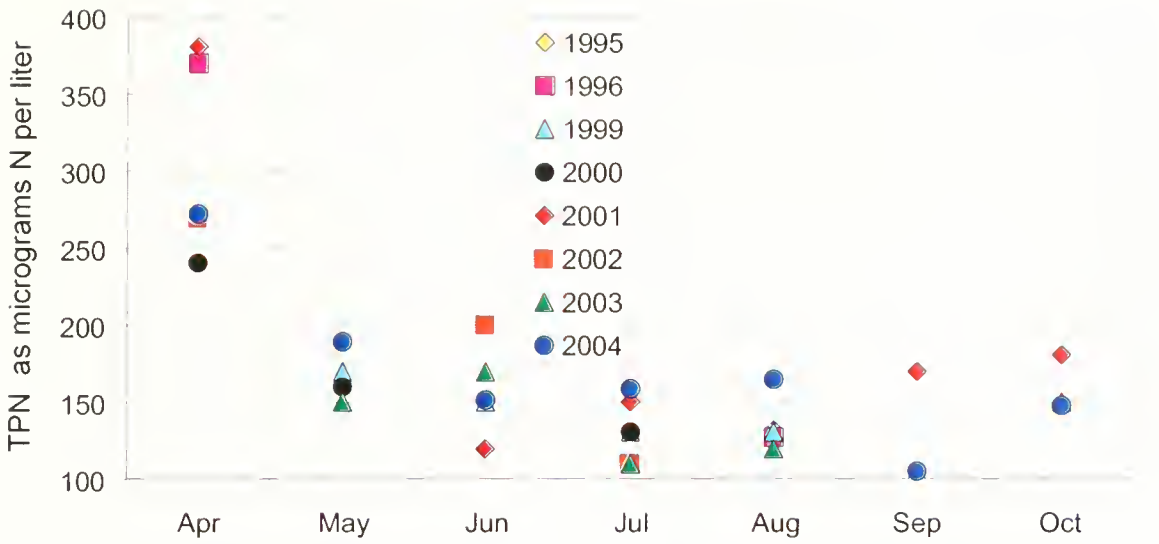

Figure 14. Whitefish River total persulfate nitrogen concentrations at USGS Gaging site, April 1995 through October 2004.

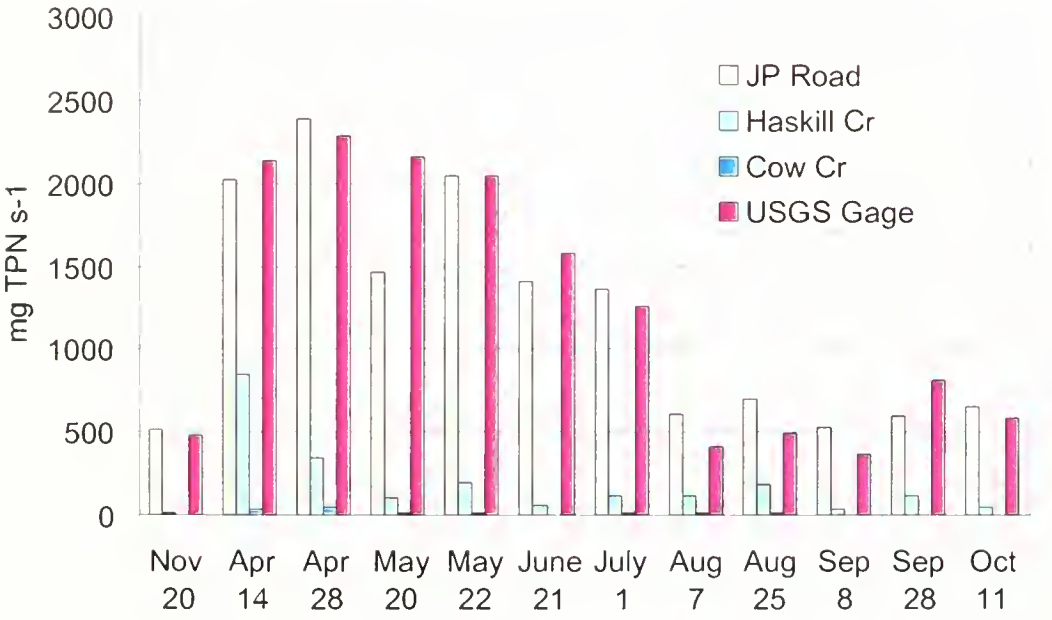

Figure 15. Sample total persulfate nitrogen loads for Whitefish River at JP Road Bridge and USGS Gage, Haskill Creek, and Cow Creek, Flathead County, MT, from November 2003 through October 2004.

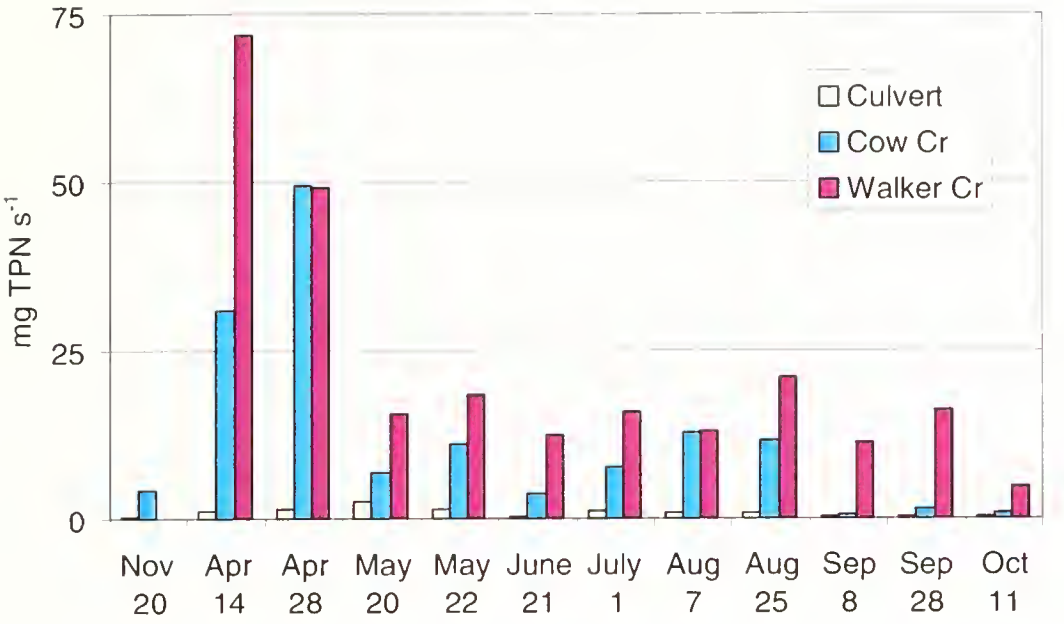

Figure 16. Sample total persulfate nitrogen loads for storm drain culvert under West Second Street bridge in Whitefish, MT, Cow Creek and Walker Creek, Flathead County, MT, from November 2003 through October 2004.

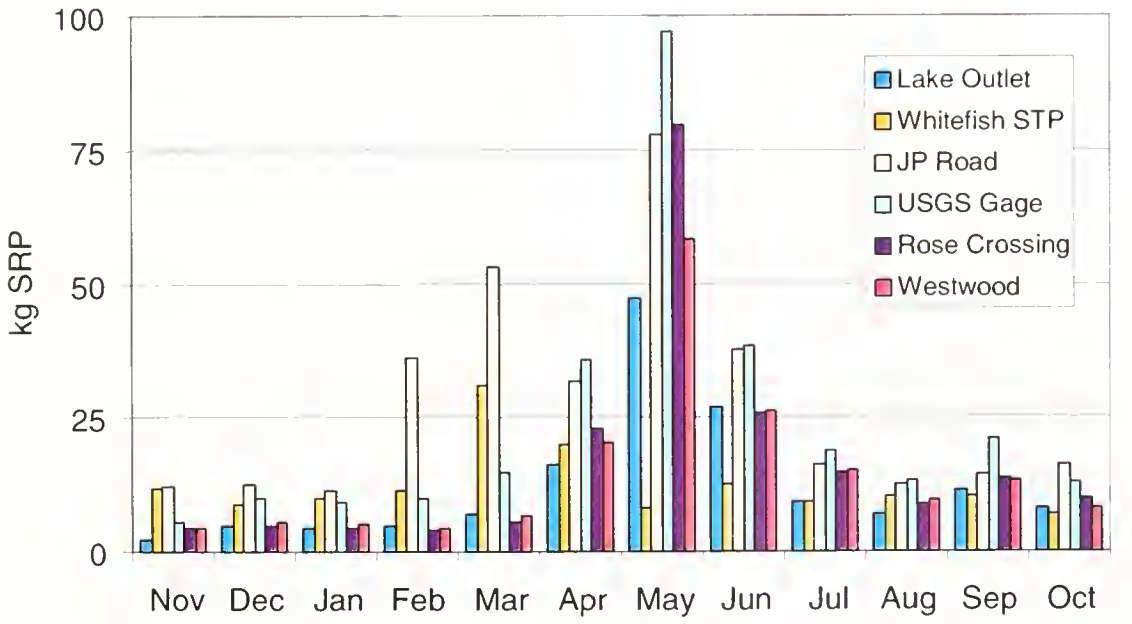

Figure 17. Whitefish River monthly soluble reactive phosphorus loads at synoptic sites, water year 2003-04.

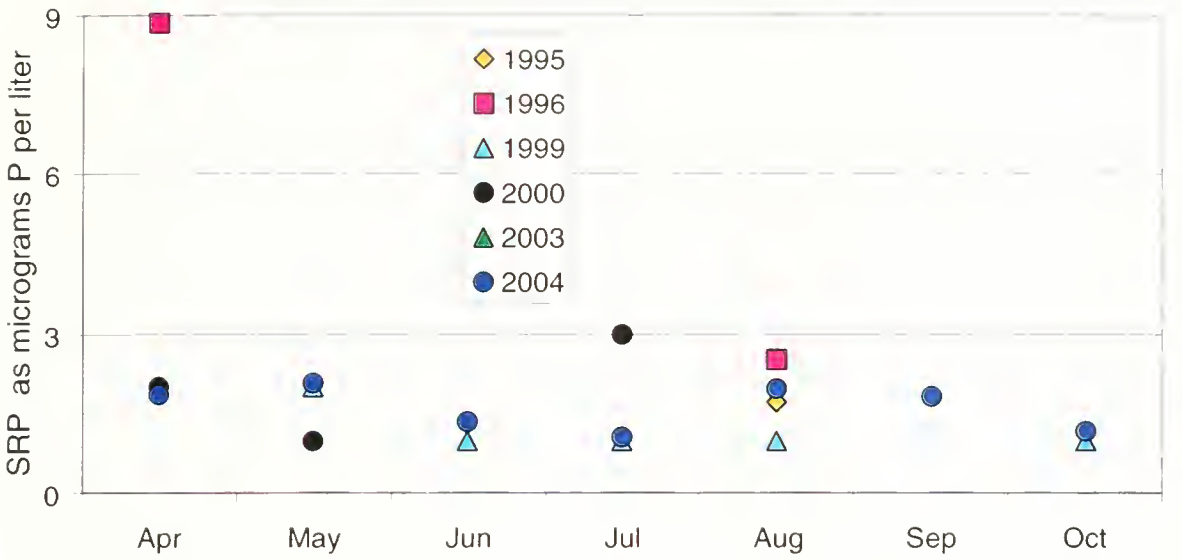

Figure 18. Whitefish River soluble reactive phosphorus concentrations at USGS Gaging site, April 1995 through October 2004.

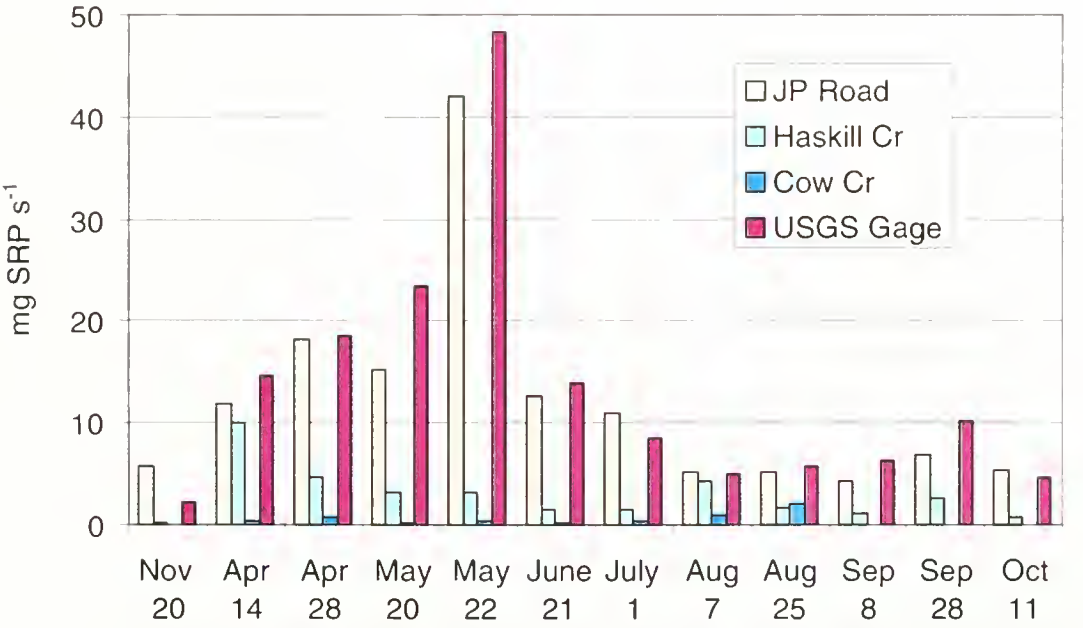

Figure 19. Sample soluble reactive phosphorus loads for Whitefish River at JP Road Bridge and USGS Gage, and Haskill Creek and Cow Creek, Flathead County, MT, from November 2003 through October 2004.

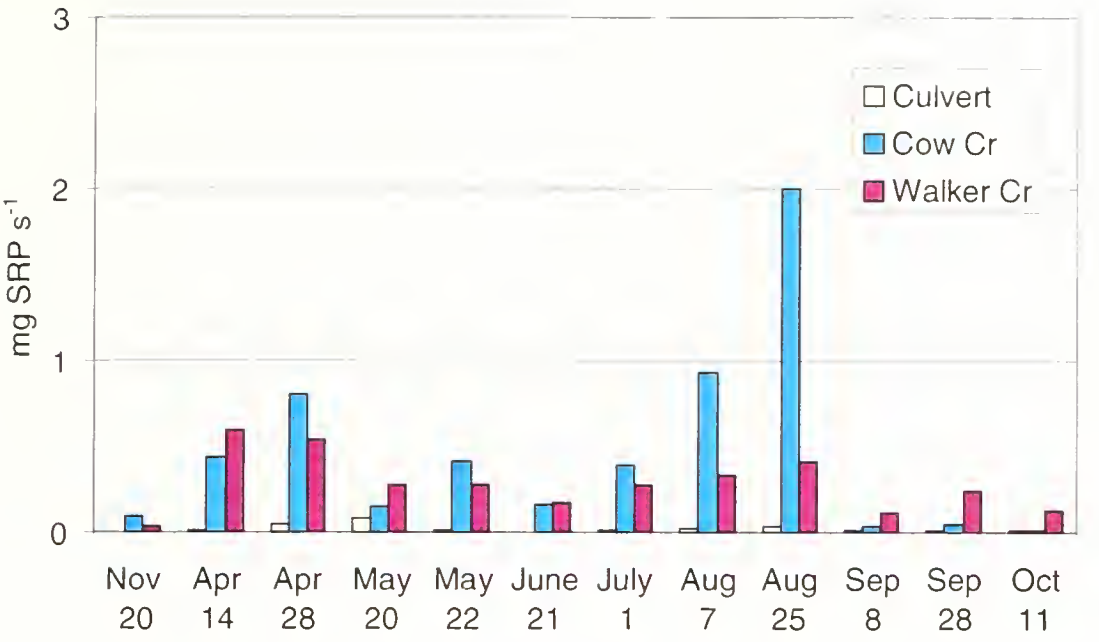

Figure 20. Sample soluble reactive phosphorus loads for storm drain culvert under West Second Street bridge in Whitefish, MT, Cow Creek and Walker Creek, Flathead County, MT, from November 2003 through October 2004.

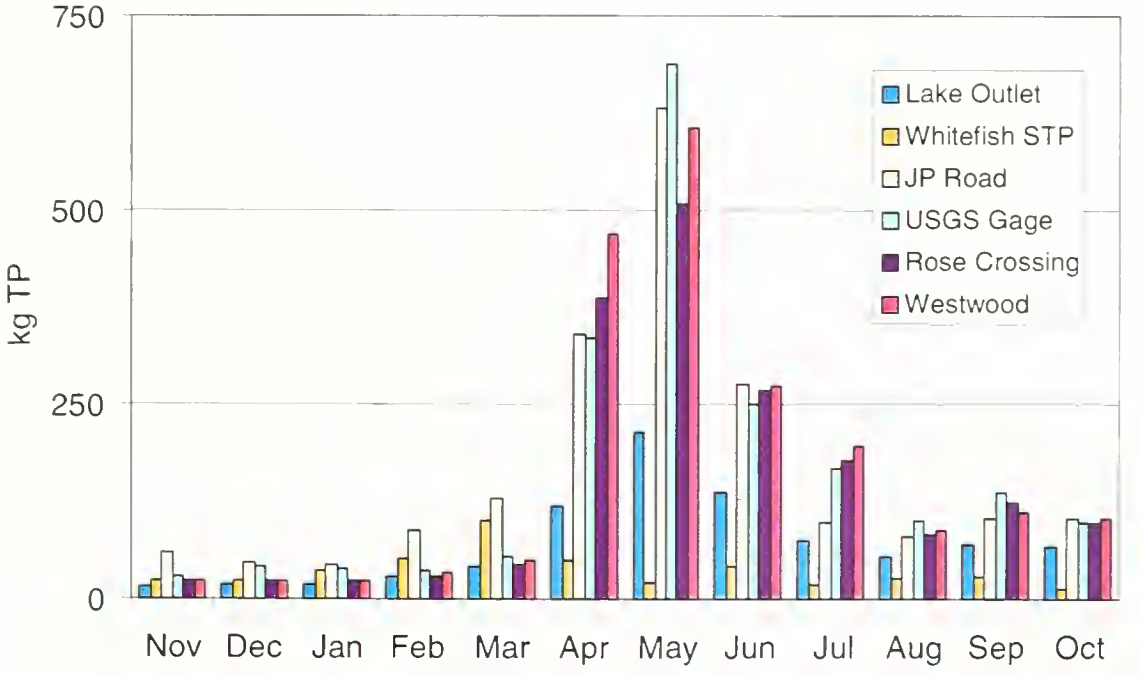

Figure 21. Whitefish River monthly total phosphorus loads at synoptic sites, water year 2003-04.

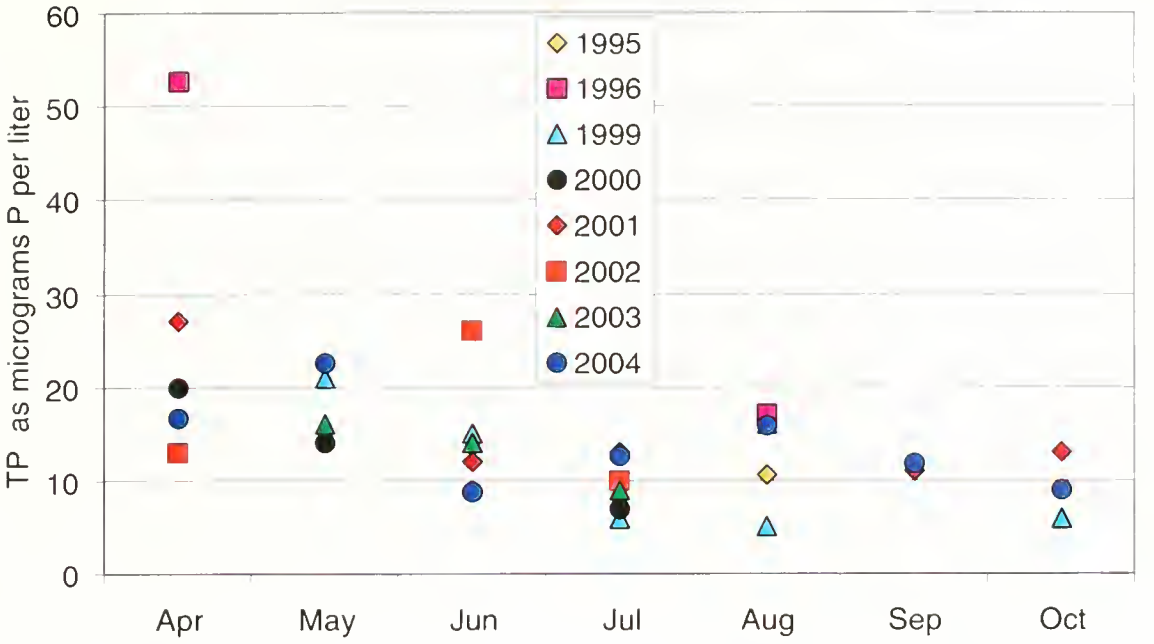

Figure 22. Whitefish River total phosphorus concentrations at USGS Gaging site, April 1995 through October 2004.

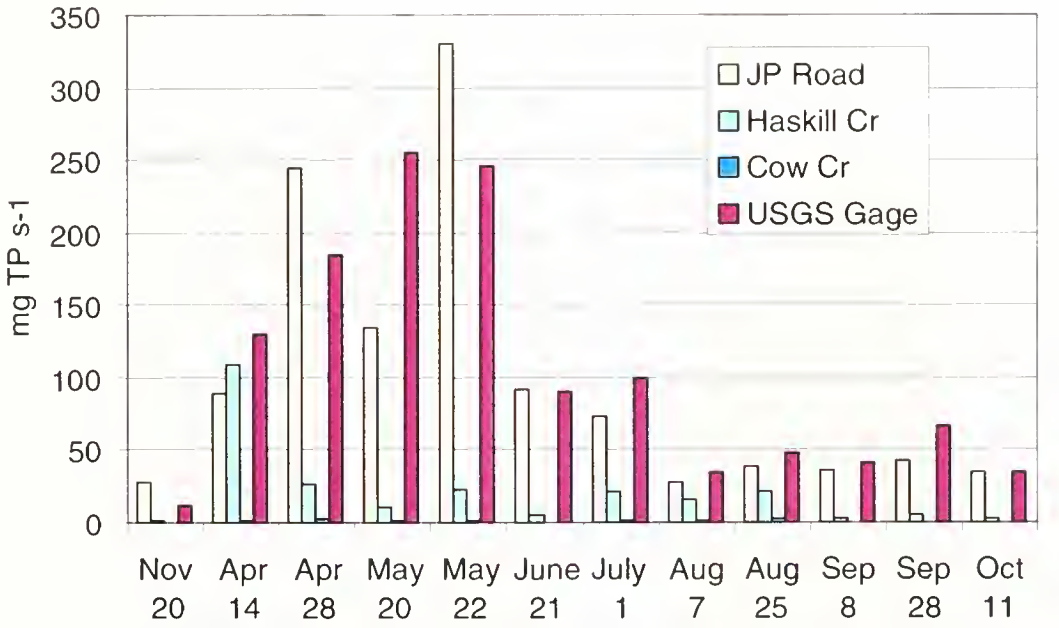

Figure 23. Sample total phosphorus loads for Whitefish River at JP Road Bridge and USGS Gage, and Haskill Creek and Cow Creek, Flathead County, MT, from November 2003 through October 2004.

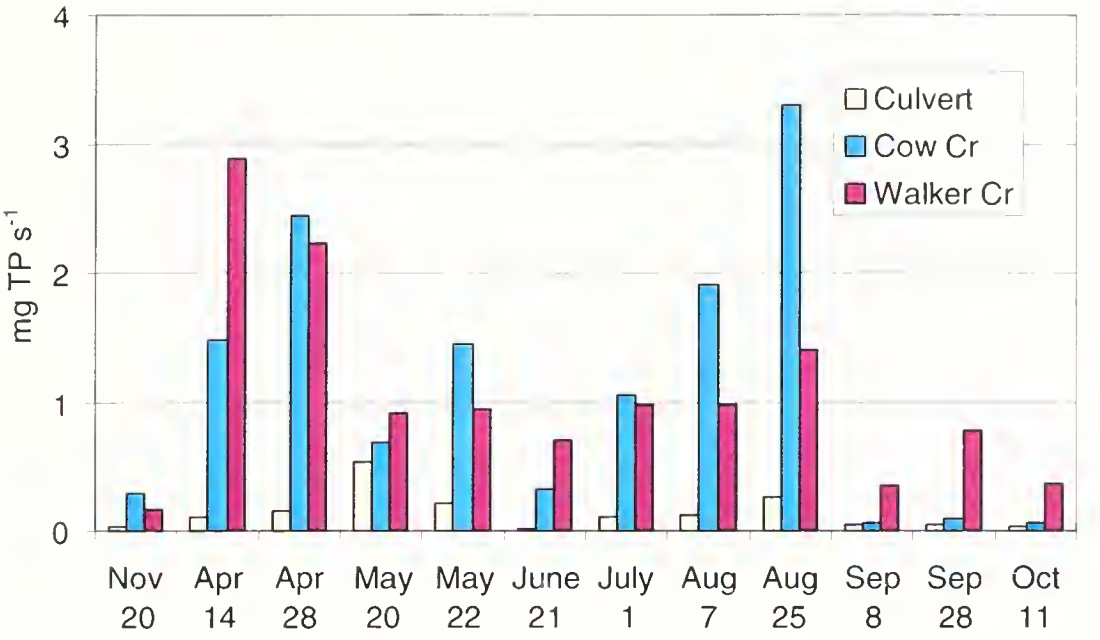

Figure 24. Sample total phosphorus loads for storm drain culvert under West Second Street bridge in Whitefish, MT, Cow Creek and Walker Creek, Flathead County, MT, from November 2003 through October 2004.

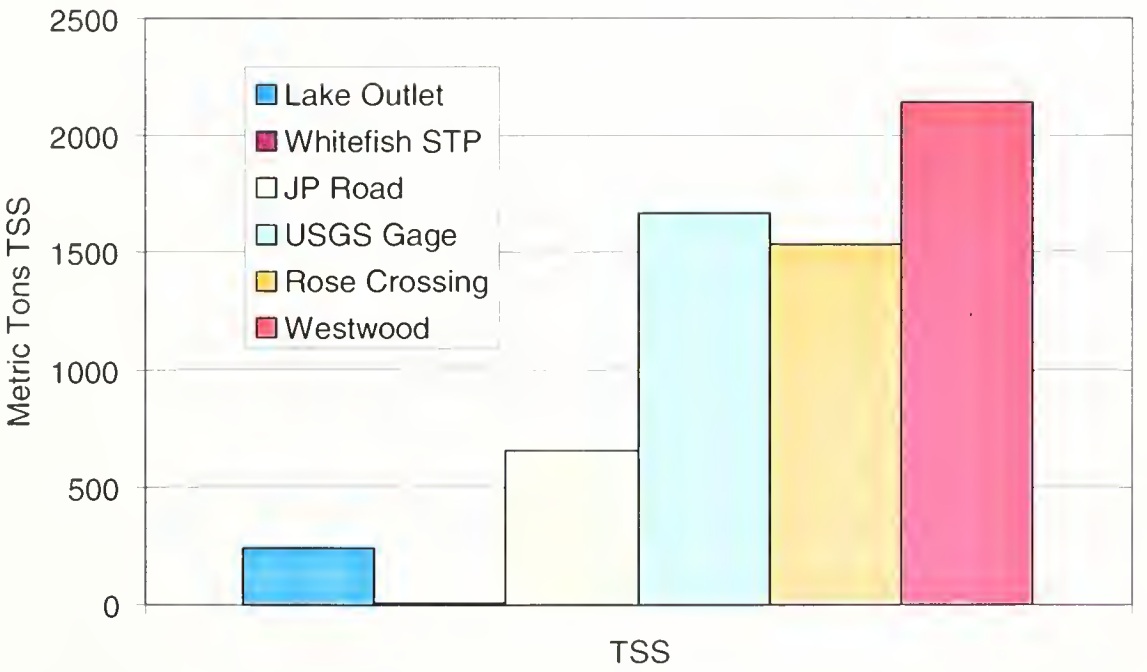

Figure 25. Whitefish River annual total suspended sediment loads at synoptic sites, water year 2003-04.

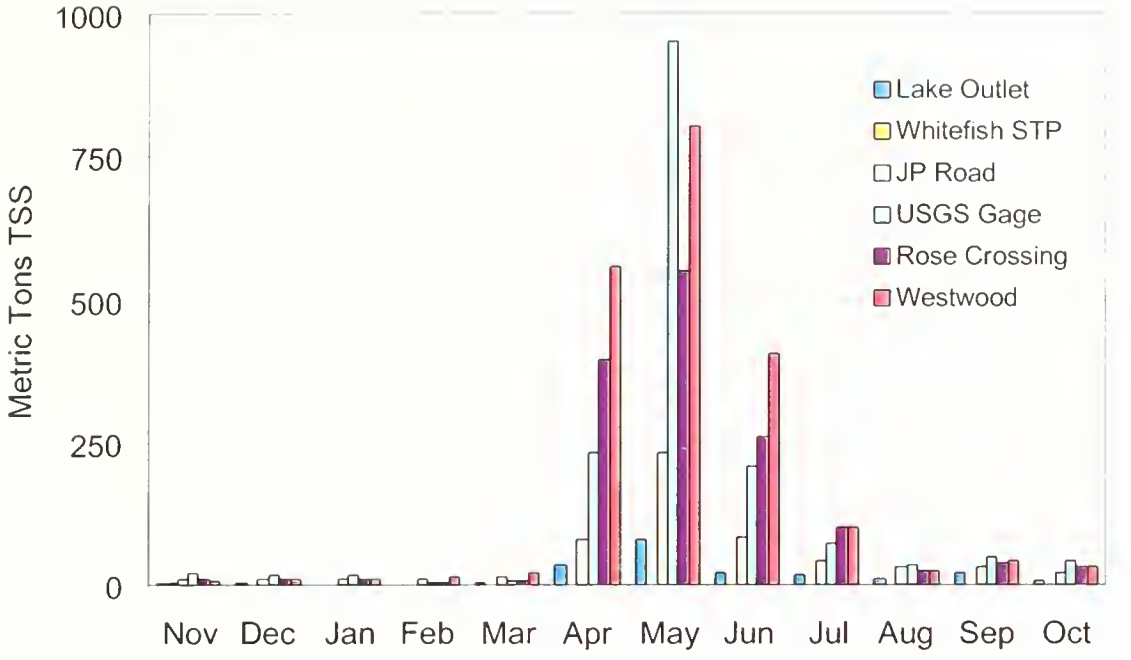

Figure 26. Whitefish River monthly total suspended sediment loads at synoptic sites, water year 2003-04.

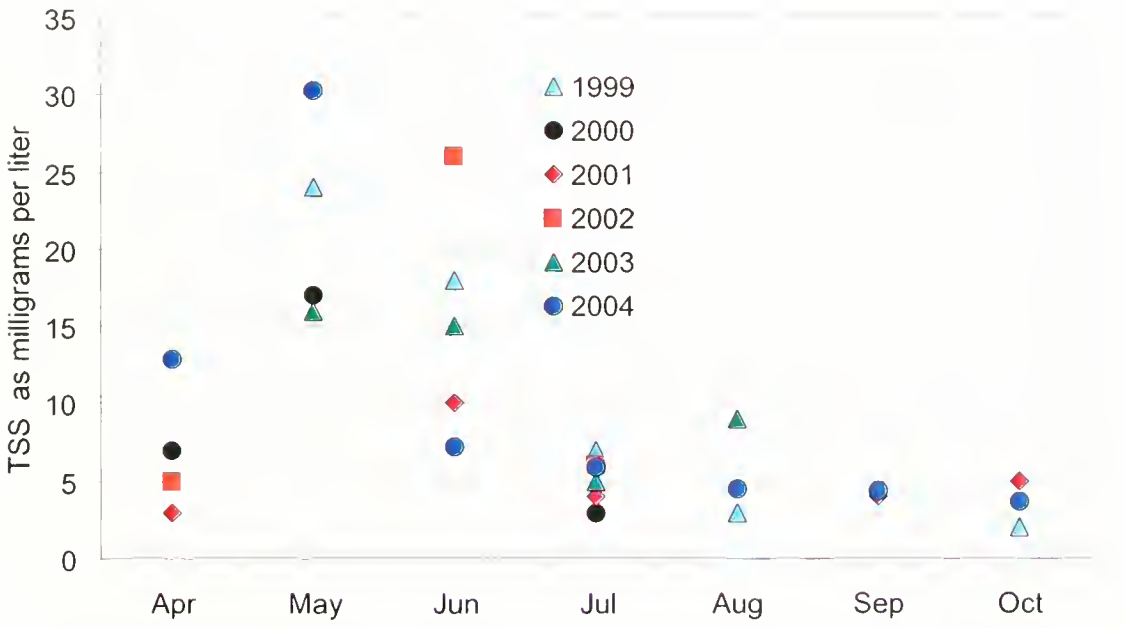

Figure 27. Whitefish River total suspended sediment concentrations at USGS Gaging site, April 1999 through October 2004.

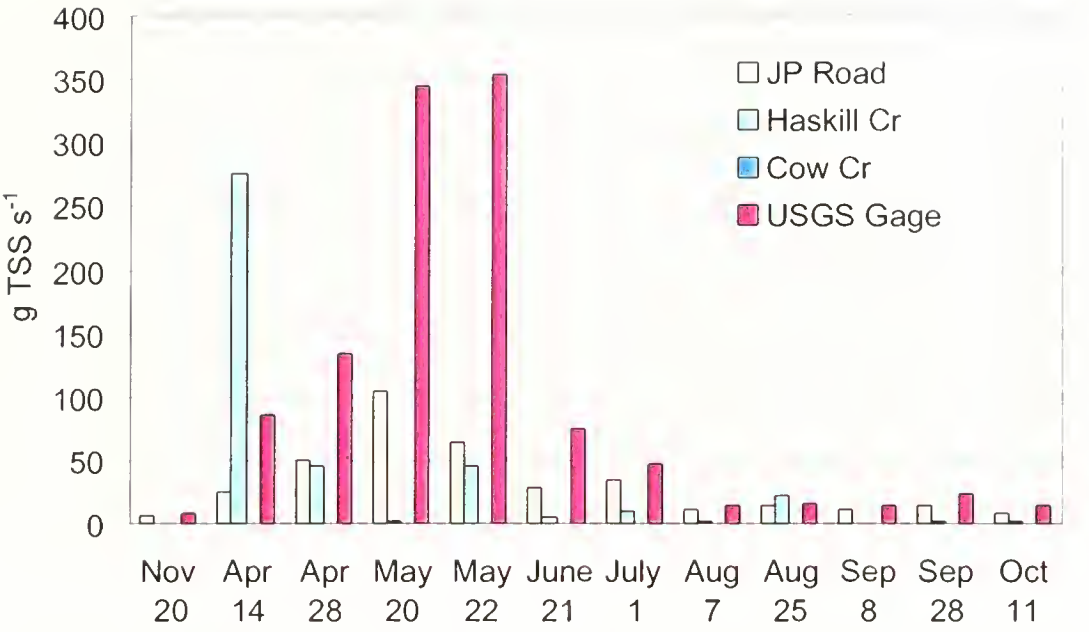

Figure 28. Sample total suspended sediment loads for Whitefish River at JP Road Bridge and USGS Gage, Haskill Creek and Cow Creek, Flathead County, MT, from November 2003 through October 2004.

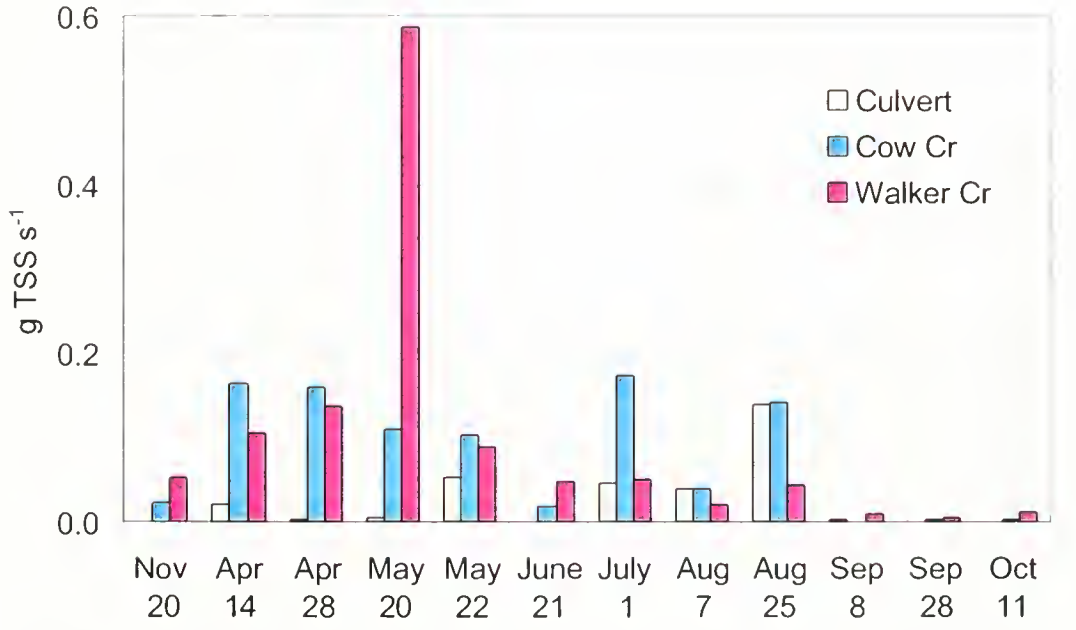

Figure 29. Sample total suspended sediment loads for storm drain culvert under West Second Street bridge in Whitefish, MT, Cow Creek and Walker Creek, Flathead County, MT, from November 2003 through October 2004.

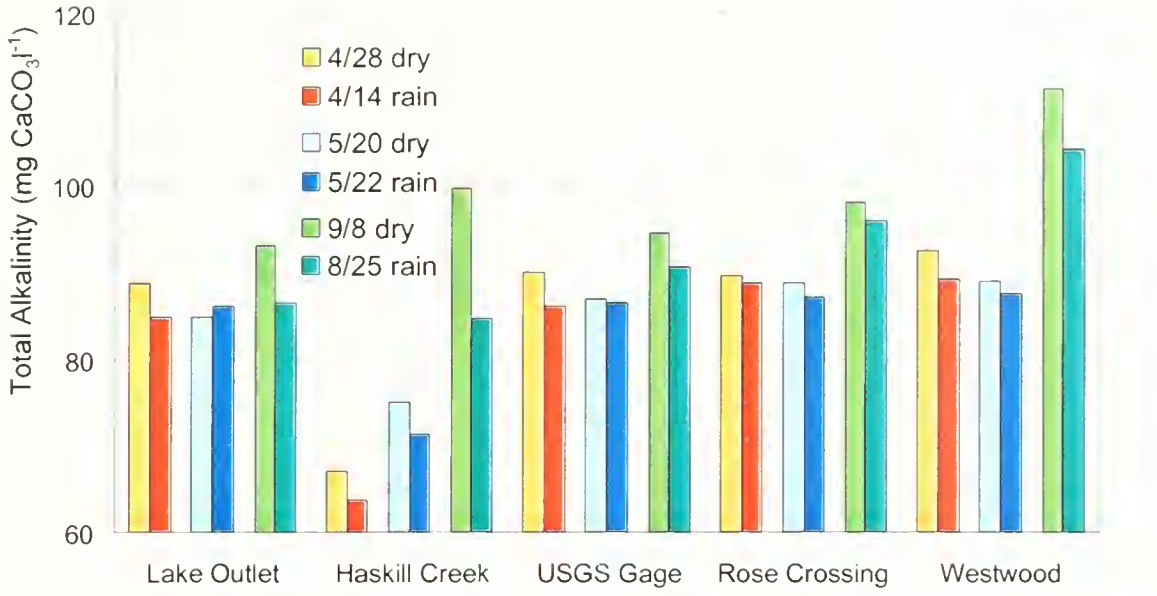

Figure 30. A comparison of total alkalinity concentrations before or after three rain events at Haskill Creek and four sampling sites on the Whitefish River, Flathead County, MT in 2004.

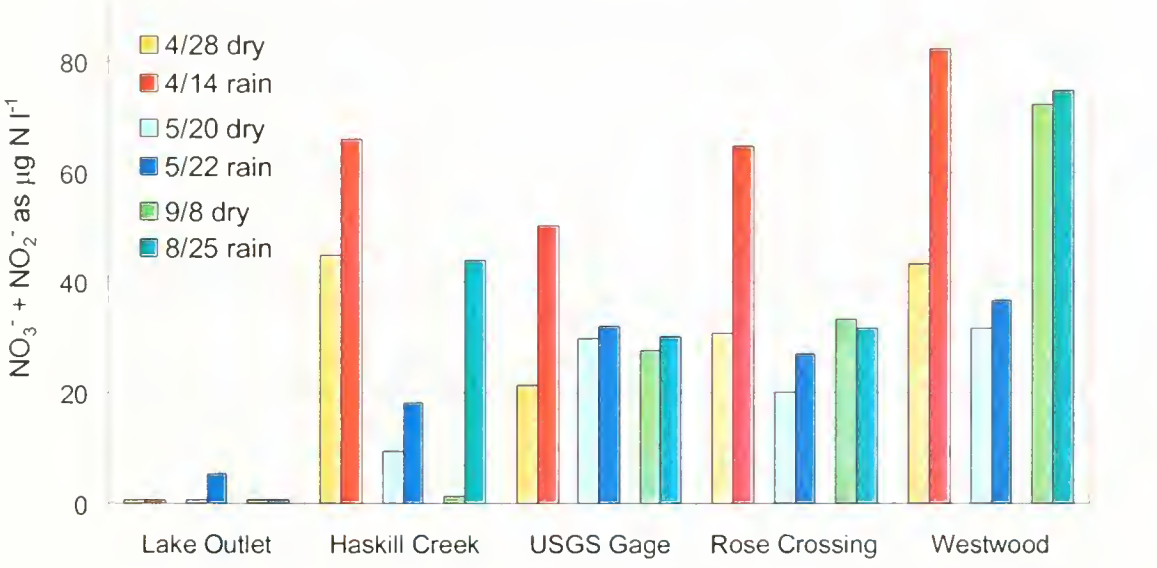

Figure 31. A comparison of nitrate + nitrite concentrations before or after three rain events at Haskill Creek and four sampling sites on the Whitefish River, Flathead County, MT in 2004.

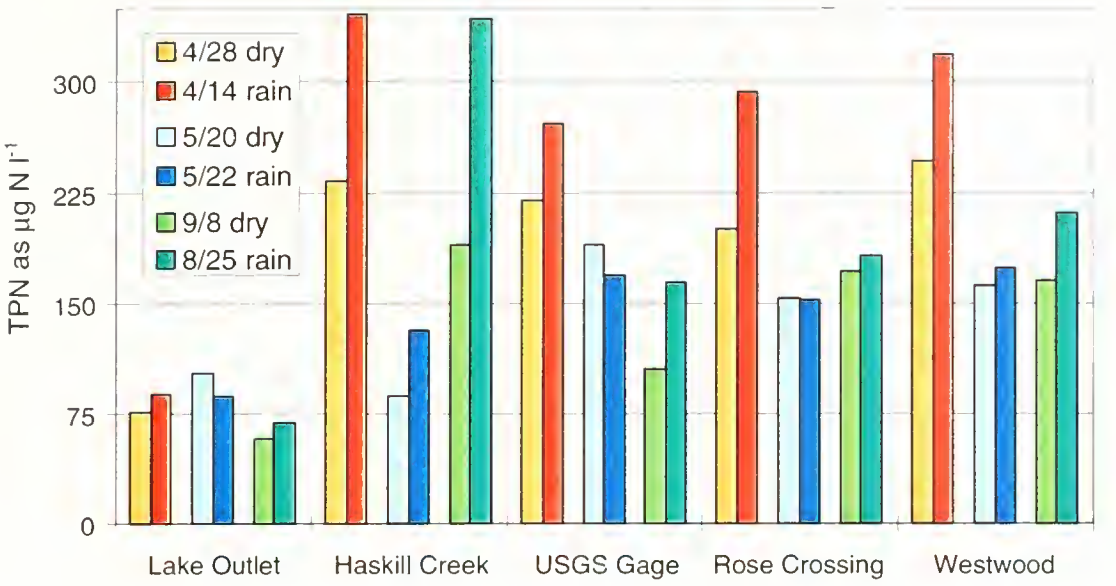

Figure 32. A comparison of total persulfate nitrogen concentrations before or after three rain events at Haskill Creek and four sampling sites on the Whitefish River, Flathead County, MT in 2004.

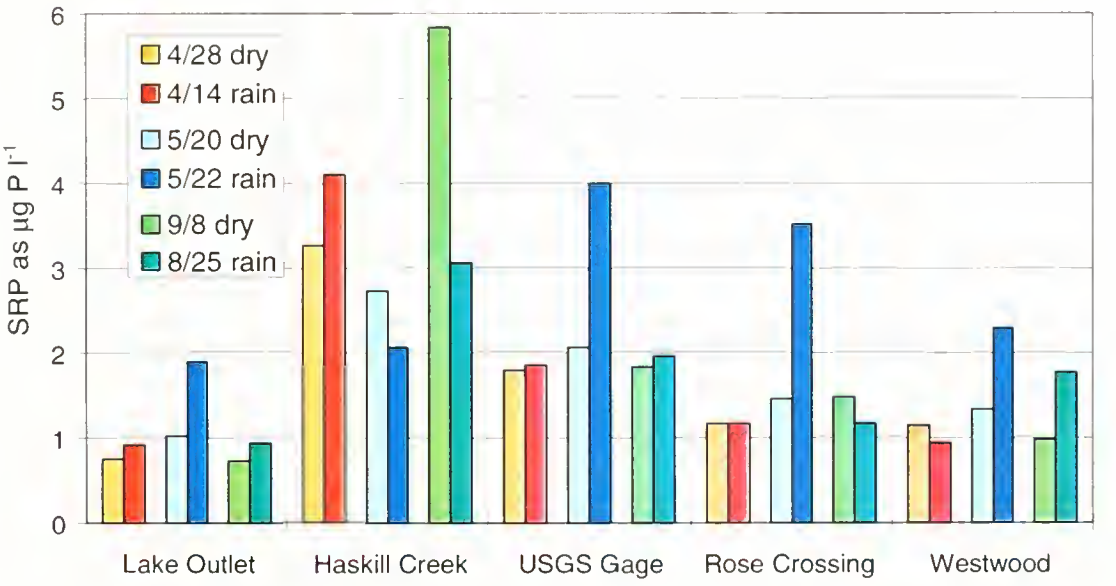

Figure 33. A comparison of soluble reactive phosphorus concentrations before or after three rain events at Haskill Creek and four sampling sites on the Whitefish River, Flathead County, MT in 2004.

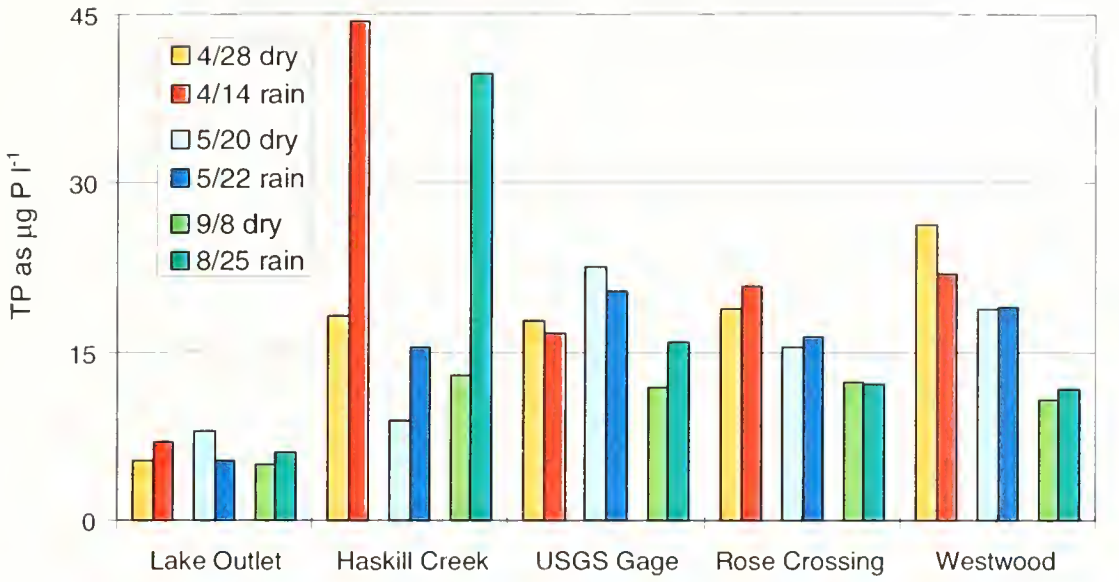

Figure 34. A comparison of total phosphorus concentrations before or after three rain events at Haskill Creek and four sampling sites on the Whitefish River, Flathead County, MT in 2004.

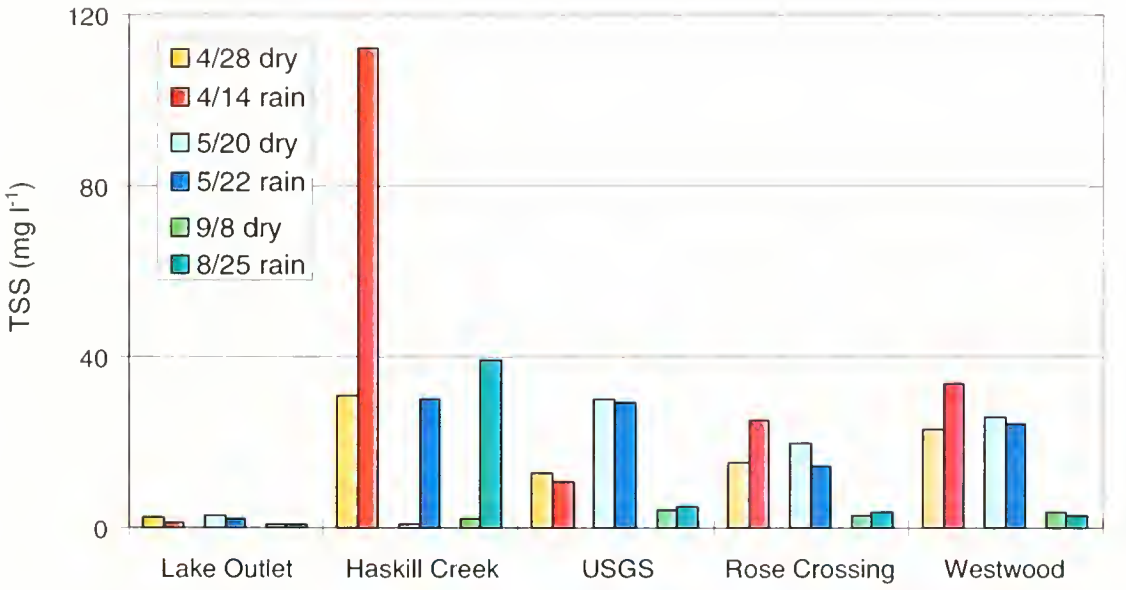

Figure 35. A comparison of total suspended sediment concentrations before or after three rain events at Haskill Creek and four sampling sites on the Whitefish River, Flathead County, MT in 2004.

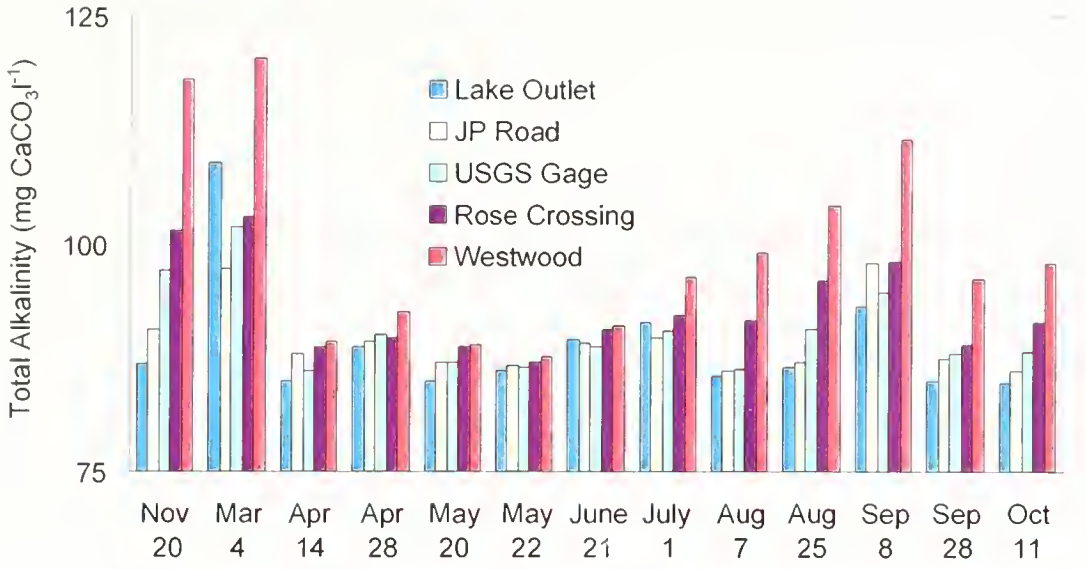

Figure 36. Whitefish River total alkalinity measured at synoptic sites, November 2003 through October 2004.

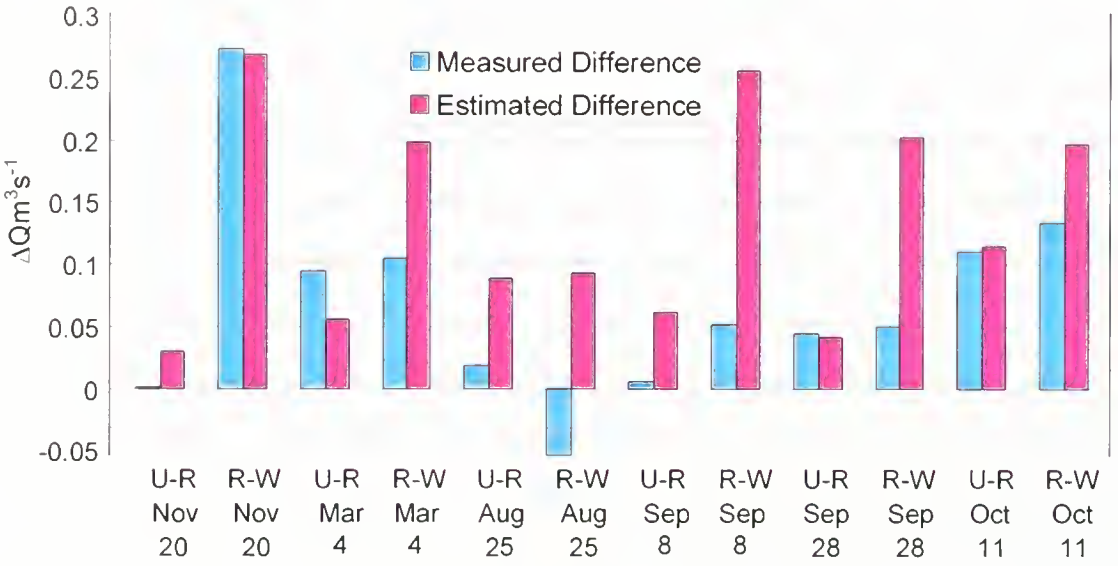

Figure 37. Estimated groundwater inputs to the Whitefish River between USGS Gage Site and Rose Crossing Site (U-R) and between Rose Crossing Site and Westwood Site (R-W) during baseflow conditions sampled in 2003 and 2004.